OIPE IAP86 SEP 0 6 2005 PATENT & TRADEMARK OFFICE

ATTORNEY DOCKET NO. 02369 #7 DAO

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RECEIVED SEP 0 9 2005 OFFICE OF PETITIONS

Applicant: WONG, Ming King
Serial No: 09/840,426
Filed: April 20, 2001
For: INTERCHANGEABLE PIEZOELECTRIC LIGHTER
Examiner:
Art Unit:

CERTIFICATE OF MAILING UNDER 37 C.F.R. §1.8(a)

The undersigned hereby certifies that this document is being placed in the United States mail with first-class postage attached, addressed to Mail Stop Petition -Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on the 1ST day of September 2005.

Susan A. Sullivan
Certifier

Mail Stop PETITIONS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PETITION TO

CORRECT ERROR IN FILING OF AN APPLICATION

Sir/Madam:

1) The instant application was filed on April 20, 2001 by prior counsel (the law firm of David & Raymond). A copy of the papers as filed is attached hereto as "Exhibit A," showing four (4) sheets of drawings related to a piezoelectric lighter.

2) A copy of a return receipt postcard showing receipt of four (4) sheets of drawings, stamped by the U.S. Patent and Trademark Office on April 20, 2001, is attached hereto as "Exhibit B."

3) On October 24, 2002 the present application was published with four (4) figures that appear to be related to a "Fuzzy Logic Device." A copy of the publication with unrelated drawings is attached hereto as "Exhibit C."

4) Applicant has searched the USPTO database and found another application filed by the law firm of David & Raymond on April 20, 2001, the same date as the filing date of the instant application and related to a "Filtering Process for Stable and Accurate Estimation." Application No. 09/840,511 filed April 20, 2001 has since issued as U.S. Patent No. 6,757,569 to LIN, attached hereto as "Exhibit D." It appears to the Applicant that the drawings filed in the instant case were inadvertently erroneously associated with drawings from the '569 patent.

5) Attached are *copies of certified copies* of Application No. 09/840,426 (the instant application) and Application No. 09/840,511 (now Patent 6,757,569) as filed on April 20, 2001, as respective "Exhibit E" and "Exhibit F." It is noted that the drawing sheets in each of these applications clearly show a filing date of "042001," and from the subject matter disclosed therein, it appears that the drawings were inadvertently mistakenly swapped between the respective applications.

6) A review of the file history of the '569 patent also shows that the same issue occurred in the '569 patent. That is, drawings related to the piezoelectric device that are the subject of the present invention were recorded as filed in the '569 invention. A copy of a Decision Granting Petition in the '569 case, and a copy of a facsimile to the USPTO dated May 22, 2003, which was treated as a Petition under 37 C.F.R. § 1.53(e), are attached hereto as "Exhibit G" and "Exhibit H," respectively.

7) Based on the information available to the Applicant, it appears that the drawings filed with the instant application, and those filed in the '569 patent, were inadvertently mistakenly swapped between the respective files at the Patent Office.

8) Moreover, there is a clear record of the proper drawings for the instant application having been received at the Patent Office on April 20, 2001 by virtue of the dated drawings (042001) of Figs. 1-4 shown in "Exhibit F."

9) Accordingly, Applicant believes that the evidence is convincing that the application papers deposited on April 20, 2001 included the four (4) correct drawing sheets, which were subsequently misplaced and/or confused with those of the '569 patent, at the time of filing in the U.S. Patent & Trademark Office on April 20, 2001, or at some time thereafter.

10) Applicant respectfully requests that the Patent Office consider the instant application complete upon filing, and grant a filing date of April 20, 2001 to the drawings and the complete application.

11) No fee is enclosed. If the Patent Office determines that a fee is due in connection with the instant Petition, it is hereby authorized to deduct such fee from our Deposit Account No. 19-0120.

Respectfully submitted,
WONG, Ming King, Applicant

Dated: August 30, 2005

By: ______________________

David M. Driscoll, Reg. No. 25,075
Applicant's Attorney
SALTER & MICHAELSON
321 South Main Street
Providence, Rhode Island 02903
Telephone: 401/421-3141
Facsimile : 401/861-1953
Customer No. 000987

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In the United States Patent and Trademark Office

Commissioner of Patents and Trademarks
Washington, District of Columbia 20231

Mailed: April 20, 2001
Attorney Docket: USP1468H-MWL

Sir:

Please file the following enclosed patent application papers:

Applicant #1, Name: Ming King WONG

Applicant #2, Name: ____

Title: Interchangeable Piezoelectric Lighter

☒ Specification, Claims, and Abstract: Nr. Of Sheets 13

☒ Declaration: Date Signed: ____

☒ Drawing(s): Nr. Of Sheets Enc.: (In Triplicate): Formal: 4 Informal: ____

☒ The applicant claims small entity status. See 37 CFR 1.27

☒ Assignment; please record and return; recordal fee enclosed.

☒ Check for $ 355.00 for:

☒ $ 355.00 for filing fee (not more than three independent claims and twenty total claims are presented).

☒ $ 40.00 Additional of Assignment is enclosed for recordal.

Very respectfully,

Signature
Raymond Y. C. Chan
Reg. Nr. : 37,484

1050 Oakdale Lane,
Arcadia, CA 91006

Certificate of Mailing

Express Mail: EL 745709553US

I hereby certify that this paper or fee is being deposited with the United States Postal Service using "Express Mail Post Office To Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to "Commissioner of Patents and Trademarks, Washington, DC 20231".

Signature: ____ Date: 04/20/2001

PTO/SB/05 (11-00)
Approved for use through 10/31/2002. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Please type a plus sign (+) inside this box → [+]

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	USP1468H-MWL
First Inventor	Ming King WONG
Title	Interchangable Piezoelectric Lighter
Express Mail Label No.	EL 745709553 US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [X] Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. [X] Applicant claims small entity status. See 37 CFR 1.27.
3. [X] Specification [Total Pages 13] (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [X] Drawing(s) (35 U.S.C. 113) [Total Sheets 4]
5. Oath or Declaration [Total Pages 1]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) (for continuation/divisional with Box 18 completed)
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
11. [ ] English Translation Document (if applicable)
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [X] Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. [ ] Request and Certification under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: ....

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: ______/______

Prior application information: Examiner ______ Group Art Unit: ______

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[ ] Customer Number or Bar Code Label (Insert Customer No. or Attach bar code label here) or [X] Correspondence address below

Name	David and Raymond Patent Group				
Address	1050 Oakdale Lane				
City	Arcadia	State	CA	Zip Code	91006
Country	USA	Telephone	626-5719812	Fax	626-5719813

Name (Print/Type)	Raymond Y. Chan	Registration No. (Attorney/Agent)	37,484
Signature	[signature]	Date	06/20/2001

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

PTO/SB/17 (11-00)
Approved for use through 10/31/2002. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

FEE TRANSMITTAL for FY 2001

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT	($) 355.00

Complete if Known

Application Number	
Filing Date	
First Named Inventor	Ming King WONG
Examiner Name	
Group Art Unit	
Attorney Docket No.	USP1468H-MWL

METHOD OF PAYMENT

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number:

Deposit Account Name:

☐ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

☒ Applicant claims small entity status. See 37 CFR 1.27

2. ☒ Payment Enclosed:

☒ Check ☐ Credit card ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	710	201	355	Utility filing fee	$355
106	320	206	160	Design filing fee	
107	490	207	245	Plant filing fee	
108	710	208	355	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 355.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	390	216	195	Extension for reply within second month	
117	890	217	445	Extension for reply within third month	
118	1,390	218	695	Extension for reply within fourth month	
128	1,890	228	945	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,240	241	620	Petition to revive - unintentional	
142	1,240	242	620	Utility issue fee (or reissue)	
143	440	243	220	Design issue fee	
144	600	244	300	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	710	246	355	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	710	249	355	For each additional invention to be examined (37 CFR § 1.129(b))	
179	710	279	355	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0

SUBMITTED BY — Complete (if applicable)

Name (Print/Type)	Raymond Y. Chan	Registration No. (Attorney/Agent)	37,484	Telephone	626-571-9812
Signature	Raymond Y. Chan			Date	04/20/2001

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

Applicant or Patentee: ______________________ Attorney's Docket No.: USP1468H-MWE
Serial or Patent No.: ______________________
Filed or Issued: ______________________
For: ______________________

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9 (f) and 1.27 (b)) – INDEPENDENT INVENTOR

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9 (c) for purposes of paying reduced fees under section 41 (a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled:
Interchangable Piezoelectric Lighter described in:

- ☒ the specification filed herewith
- ☐ application serial no. ____________, filed ____________
- ☐ patent no. ____________, issued ____________

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9 (c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9 (d) or a non profit organization under 37 CFR 1.9 (e).
Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- ☐ no such person, concern, or organization
- ☒ person, concern or organizations listed below *

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

FULL NAME Ming Wide Lighter Co., Ltd.
ADDRESS 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong
☐ INDIVIDUAL ☒ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME ______________________
ADDRESS ______________________
☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME ______________________
ADDRESS ______________________
☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28 (b))
I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statements is directed.

Ming King Wong		
NAME OF INVENTOR	NAME OF INVENTOR	NAME OF INVENTOR
Signature of Inventor	Signature of Inventor	Signature of Inventor
04/18/2001		
Date	Date	Date

Attorney/Docket No: USP1468A-MWL

DECLARATION FOR UTILITY PATENT APPLICATION

As a below named inventor, I hereby declare that:
My residence, mailing address, and citizenship are as stated below next to my name.
I believe I am the original, first and sole inventor (if only one name is lited below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Interchangable Piezoelectric Lighter,

the specification of which is attached hereto unless the following box is checked:

☐ was filed on ______________ as United States Application Number or PCT International Application Number ______________ and was amended on ______________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.
I acknowledge the duty to disclose information which is materid to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing data of the prior application and the national or PCT international filing date of the continuation-in-part application.
I hereby claim foreign priority benefits under 35 USC 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country otherthan the United States of America, listed below and have also identified below, by checking bos, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

			Priority Claimed	Certified Copy Attached
(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No	☐ Yes ☐ No
(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No	☐ Yes ☐ No
(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No	☐ Yes ☐ No

☐ Additional foreign application numbers are listed on a supplemental priority data sheet attached hereto.

I hereby claimed the benefit under 35 USC 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (Day/Month/Year)

☐ Additional provisional application numbers are listed on a supplemental priority data sheet attached hereto.

I hereby appoint the following attorney(s) and/or agent(s), with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Raymond Yat Chan, Reg. No. 37,484
Address all correspondence to: **1050 Oakdale Lane, Arcadia, CA 91006-2222, U.S.A.**
Telephone Calls to: **(626) 571-9812**
Facsimile Calls to: **(626) 571-9813**

I hereby declare that all Statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor (given name, family name) Ming King Wong

Inventor's signature ______________ Date 04/18/2001
Residence Same as below Citizenship Hong Kong, P.R.C.
Mailing Address 12/F, ~~North Point Ind.~~, Bldg., 499 King's Road, North Point, Hong Kong

Full name of second joint inventor, if any (given name, family name) ______________

Second Inventor's signature ______________ Date ______________
Residence ______________ Citizenship ______________
Mailing Address ______________

☐ Additional inventors are being named on separately numbered sheets attached hereto.

FORM PTO-1595 (Modified)
(Rev. 6-93)
OMB No. 0651-0011 (exp.4/94)

P08/REV01

RECORDATION FORM COVER SHEET

PATENTS ONLY

U.S. DEPARTMENT OF COMMERCE
Patent and Trademark Office

Tab settings

To the Honorable Commissioner of Patents and Trademarks: Please record the attached original documents or copy thereof.

1. Name of conveying party(ies):
Ming King WONG

Additional names(s) of conveying party(ies) attached? ☐ Yes ☒ No

2. Name and address of receiving party(ies):

Name: Ming Wide Lighter Co., Ltd.

Internal Address: 12/F, North Point Ind., Bldg.,
499 King's Road, North Point, Hong Kong

Street Address: Same as above

City: ______ State: ______ ZIP: ______

Additional name(s) & address(es) ☐ Yes ☒ No

3. Nature of conveyance:

☒ Assignment ☐ Merger
☐ Security Agreement ☐ Change of Name
☐ Other ______

Execution Date: 04/18/2001

4. Application number(s) or registration numbers(s):

If this document is being filed together with a new application, the execution date of the application is: 04/18/2001

A. Patent Application No.(s)

B. Patent No.(s)

Additional numbers ☐ Yes ☒ No

5. Name and address of party to whom correspondence concerning document should be mailed:

Name: David and Raymond Patent Group

Internal Address: 108 N. Ynez Ave., Suite 128
Monterey Park, CA 91754, USA

Street Address: Same as above

City: ______ State: ______ ZIP: ______

6. Total number of applications and patents involved: 01

7. Total fee (37 CFR 3.41):..................$ 40.00

☒ Enclosed

☐ Authorized to be charged to deposit account

8. Deposit account number:

(Attach duplicate copy of this page if paying by deposit account)

DO NOT USE THIS SPACE

9. Statement and signature.

To the best of my knowledge and belief, the foregoing information is true and correct and any attached copy is a true copy of the original document.

Raymond Y. Chan — [signature] — 04/30/2001

Name of Person Signing — Signature — Date

Total number of pages including cover sheet, attachments, and 04

ASSIGNMENT

WHEREAS, I (we), Ming King Wong whose post office address(es) appear(s) below, hereinafter referred to as ASSIGNOR, have invented a certain new and useful improvements in
Interchangable Piezoelectric Lighter
(hereinafter referred to as the INVENTION) for which an application for United States Letters Patent was

- ☒ executed on even data herewith
- ☐ executed on:
- ☐ filed on: Serial No.:

WHEREAS, Ming Wide Lighter Co., Ltd. whose post office address is 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong hereinafter referred to as ASSIGNEE, is desirous of acquiring the entire right, title and interest in and to the same in the United States;

NOW, THEREFORE, for good and valuable consideration, receipt of which is hereby acknowledged, I (we), ASSIGNOR, by these presents do sell, assign and transfer unto said ASSIGNEE, the entire right, title, and interest in and to said INVENTION and application throughout the United States of America, including any and all Letters Patent granted on any division, continuation, continuation -in-part and reissue of said application.

ALSO, ASSIGNOR hereby agrees to execute any documents that legally may be required in connection with the filing, prosecution and maintenance of said application or any other patent application(s) in the United States for said INVENTION, including additional documents that may be required to affirm the rights of ASSIGNEE in and to said INVENTION, all without further consideration. ASSIGNOR also agrees, without further consideration and at ASSIGNEE'S expense, to identify and communicate to ASSIGNEE at ASSIGNEE'S request documents and information concerning the INVENTION that are within ASSIGNOR'S possession or control, and to provide further assurances and testimony on behalf of ASSIGNEE that lawfully may be required of ASSIGNOR in respect of the prosecution, maintenance and defense of any patent application or patent encompassed within the terms of this instrument. ASSIGNOR'S obligations under this instrument shall extend to ASSIGNOR'S heirs, executors, administrators and other legal representatives.

ALSO, ASSIGNOR hereby authorizes and requests the Commissioner of Patents and Trademarks to issue any and all Letters Patent referred to above to ASSIGNEE, as the ASSIGNEE of the entire right, title and interest in and to the same, for ASSIGNEE'S sole use and behoof; and for the use and behoof of ASSIGNEE'S legal representatives and successors, to the full end of the term for which such Letters Patent may be granted, as fully and entirely as the same would have been held by ASSIGNOR had this assignment and sale not been made.

ASSIGNOR authorizes Raymond Yat Chiu Chan to insert or complete any information in this document needed to effect its recordal in the U.S. Patent and Trademark Office.

ASSIGNOR NAME: Ming King Wong

ADDRESS: 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong

SIGNATURE ______________________ 04/18/2001
DATE

Applicant or Patentee: ______
Serial or Patent No.: ______
Filed or Issued: ______
For: ______

Attorney's Docket No.: USP1468A-MWL

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9 (f) and 1.27 (c)) – SMALL BUSINESS CONCERN

I hereby declare that I am
- [ ] the owner of the small business concern identified below:
- [x] an official of the small business concern empowered to act on behalf of the concern identified below:

Name of Concern: Ming Wide Lighter Co., Ltd.
Address of Concern: 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9 (d), for purposes of paying reduced fees under section 41(a) and (b) of title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power of control the other, or a third party or parties controls or has the power to control both.
I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention entitled:
Interchangable Piezoelectric Lighter
described in:
- [x] the specification filed herewith
- [ ] application serial no. ______, filed ______
- [ ] patent no. ______, issued ______

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below * and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(d) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as a small entities. (37 CFR 1.27)

Full Name:
Address:
- [ ] INDIVIDUAL
- [x] SMALL BUSINESS CONCERN
- [ ] NON PROFIT ORGANIZATION

Full Name:
Address:
- [ ] INDIVIDUAL
- [ ] SMALL BUSINESS CONCERN
- [ ] NON PROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28 (b))
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Name of Person Signing: Ming King Wong
Title of Person Other than Owner: Officer
Address of Person Signing: 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong

Signature ______ Date 04/18/2001

USP1468H-MWL

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Ming King Wong

Filing Date: ______

Serial No.: ______

Examiner: ______

Art Unit: ______

Title Interchangable Piezoelectric Lighter

To: The Commissioner of
Patents and Trademarks
Washington, D.C. 20231

POWER OF ATTORNEY

As a named assignee of the entire interest of the above identified application, I hereby appoint the following attorney(s) and/or agent(s) to prosecute the application identified above, and to transact all business in the Patent and trademark Office connected therewith:

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TITLE: Officer
ADDRESS: 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong

SIGNATURE ______ DATE 04/18/2001

Title

Interchangeable Piezoelectric Lighter

Background of the Present Invention

Field of Invention

The present invention relates to piezoelectric lighters, and more particularly to an interchangeable piezoelectric lighter which is adapted for selectively interchanging a type of flame between a visible flame, a torch flame, and a windproof flame.

Description of Related Arts

Piezoelectric lighters have been known and sold throughout the United States. The conventional piezoelectric lighters are generally classified into two categories which is the visible flame type piezoelectric lighter and the torch flame type piezoelectric lighter. The visible flame type piezoelectric lighter, such as a cigarette lighter, allows gas emitted from the nozzle directly burned in the air to produce a regular visible flame. A windproof type piezoelectric lighter, has a re-igniting properties wherein an ignition element is heated up when igniting the lighter in such a manner that once the flame is blown out, the ignition element remains in high temperature and re-ignites the emitted gas to regain the flame. Thus, a torch lighter is adapted for providing a high temperature torch flame wherein the torch flame is more powerful than the visible flame so as to increase the burning purpose of the lighter.

For smokers, especially cigar and pipe smokers, do not ready like to use the torch flame type piezoelectric lighter since the high temperature torch flame will destroy the taste of the tobacco. However, it is a hassle for the smoker to light a cigarette or a cigar outdoors while using the visible flame type piezoelectric lighter. Thus, it is inconvenient for the smokers to carry different types of lighter at once.

Moreover, an improved piezoelectric lighter is adapted for selecting the flame by manipulating an ignition button wherein when a downward force is applied on the

ignition button to depress the ignition button, such lighter provides a torch flame and when the downward force is released, the lighter provides a visible flame. However, a user must manipulate the ignition button and leads to different operational results depending on the user, which may be considered disadvantageous in practical use. Thus, the lighter must require other parts to incorporate therewith for controlling a flow of gas. Generally, a lighter cap is incorporated with the lighter for actuating a valve thereof such that when the lighter cap is opened, the gas is released from the gas chamber through the valve. This adverse result affects the ease of leaking the gas from the gas chamber. So, such improved lighter still has drawbacks in practical use and hence there has been a demand for an interchangeable lighter which is improved in both safety and operability.

Summary of the Present Invention

A main object of the present invention is to provide an interchangeable piezoelectric lighter which is adapted for selectively interchanging a type of flame between a visible flame, torch flame, and a windproof flame.

Another object of the present invention is to provide an interchangeable piezoelectric lighter which produces both visible flame, windproof flame, and torch flame for selectively lighting a cigarette, cigar and pipe conveniently.

Another object of the present invention is to provide an interchangeable piezoelectric lighter wherein the visible flame, the torch flame, and the windproof flame are selectively produced by controlling a flame interchanging means such that no mechanism is required for users to manipulate in order to select the flame such as the ignition button.

Another object of the present invention is to provide an interchangeable piezoelectric lighter wherein the lighter is improved in both safety and operability. A user selects a desired flame by manipulating the flame interchanging means and then ignites the lighter in one single action, which is advantageous in practical use.

Accordingly, in order to accomplish the above objects, the present invention provides an interchangeable piezoelectric lighter, comprising:

a casing receiving a liquefied gas storage and a switcher cavity provided therein;

a gas valve operatively extended from the liquefied gas storage for controlling a flow of gas;

a piezoelectric unit fitted in the casing for generating piezoelectricity;

an ignition button slidably fitted in the casing in a vertically movable manner wherein the ignition button is attached to a top end of the piezoelectric unit and arranged to compress the piezoelectric unit when the ignition button is depressed; and

a flame interchanging means for selectively interchanging a flame of the piezoelectric lighter, comprising a valve switcher movably received in the switcher cavity wherein the valve switcher comprises at least two gas nozzles selectively and coaxially aligning with the gas valve for the flow of gas passing therethrough so as to produce different flames.

Brief Description of the Drawings

Fig. 1 is a perspective view of an interchangeable piezoelectric lighter according to a preferred embodiment of the present invention.

Fig. 2 is an exploded perspective view of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

Fig. 3 is a sectional view of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

Fig. 4 illustrates an alternative mode of a flame interchanging means of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiment

Referring to Figs. 1 to 3 of the drawings, an interchangeable piezoelectric lighter according to a preferred embodiment of the present invention is illustrated. The interchangeable piezoelectric lighter, such as a standard piezoelectric lighter, comprises a casing 10 receiving a liquefied gas storage 11 and a switcher cavity 12 provided therein, a gas valve 13 operatively extended from the liquefied gas storage 11 for controlling a flow of gas, a piezoelectric unit 14 fitted in the casing 10 for generating piezoelectricity, and an ignition button 15 slidably fitted in the casing 10 in a vertically movable manner.

The piezoelectric unit 14, which is disposed in the casing 10, comprises a movable operating part 141 extended upwardly and an ignition tip 142 extended to a position towards to the gas valve 13, wherein when the movable operating part 141 is depressed downwardly, the ignition tip 142 generates sparks to ignite the gas emitted from the gas valve 13 at the same time.

The ignition button 15 is attached to a top end of the movable operating part 141 of the piezoelectric unit 13 and operatively connected to the gas valve 13 via a gas lever 16. Accordingly, when the ignition button 15 is pushed downward, the movable operating part 141 of the piezoelectric unit 14 is compressed for generating piezoelectricity through and out the ignition tip 142. At the same time, the gas lever 16 is simultaneously pressed by the ignition button 15 to release gas through the gas valve 13 so as to ignite the releasing gas by the spark from the ignition tip 142.

The interchangeable piezoelectric lighter further comprises a flame interchanging means 20 for selectively interchanging a flame of the piezoelectric lighter, comprising a valve switcher 21 movably received in the switcher cavity 12 in a rotatably movable manner wherein the valve switcher 21 comprises at least two gas nozzles 211 selectively and coaxially aligning with the gas valve 13 for the flow of gas passing therethrough so as to produce different flames.

The valve switcher 21 has a lower portion exposed to an exterior of the casing 10 wherein a plurality of flanges 214 are spacedly protruded on an outer circumferential surface of the lower portion of the valve switcher 21 for being rotated easily and an upper portion rotatably received in a cover 18 which is supported on the casing 10. The cover 18 has a through hole 181 provided thereon and arranged to align with gas valve 13 for

the flame passing through. Thus, a cap 19 is pivotally mounted on the cover 18 for protecting the valve nozzle 211.

The flame interchanging means 20 further comprises a gas adapter 22 fitted in the switcher cavity 12 wherein the valve switcher 21 is supported thereon and a gas emitter 22, made of conductive material, having an inlet end operatively extended from the gas valve 13 and a gas releasing end penetrated through the gas adapter 22 so as to selectively align with one of the gas nozzles 211, 212.

According to the preferred embodiment, the valve switcher 21 having a circular shaped rotatably and sealedly mounted on the gas adapter 22 wherein the valve switcher 21 comprises three gas nozzles 211, which are a visible gas nozzle 211a, a torch nozzle 211b, and a windproof nozzle 211c, axially provided on the valve switcher 21 respectively, so as to selectively align with the gas emitter 23. Each of the three gas nozzles 211 has a nozzle head 213 appearing from a ceiling of the valve switcher 21 and a gas inlet 212 provided on a bottom surface of the valve switcher 21 and adapted for sealedly aligning with the gas releasing end of the gas emitter 23 such that the releasing gas is adapted for transmitting from the gas valve 13 to the respective gas nozzle 211 through the gas emitter 23, as shown in Fig. 3.

Accordingly, a gas conduit 17, which is made of non-conductive material such as plastic, is connected between the gas valve 13 and the gas emitter 23 wherein the ignition tip 142 is extended to a position close to the gas emitter 23 in such a manner that the piezoelectricity generated by the piezoelectric unit 14 is transmitted to the gas emitter 23 by conduction for igniting the releasing gas from the gas valve 13. However, the piezoelectricity cannot transmit to the gas valve 13 through the gas conduit 17 because the gas conduit 17 functions as a resistance for resisting the piezoelectricity transmitting therethrough.

The flame interchanging means 20 further comprises a guiding unit 24 for guiding the gas emitter 23 aligned with the respective gas nozzle 211 wherein the guiding unit 24 comprises at least a protrusion 241 upwardly provided on a top surface of the gas adapter 22 and at least a corresponding indention 242 formed on a bottom surface of the valve switcher 21 in such a manner that the protrusion 241 is fittedly engaged with the indention 242 when the gas emitter 23 is aligned with the respective gas nozzle 211, so as to ensure the alignment thereof.

The interchangeable piezoelectric lighter further comprises a supporting frame 30 comprising a central shaft 31 upwardly extended from the switcher cavity 12 wherein the valve switcher 21 is rotatably supported by the central shaft 31 and a resilient element 32 coaxially mounted on the central shaft 31 for applying an urging force against the gas adapter 22.

Accordingly, the valve switcher 21 has a center slot 210 coaxially formed on a bottom surface thereof and the gas adapter 22 has a center through hole 220 coaxially formed thereon in such a manner that the central shaft 31 is penetrated through the center through hole 220 of the gas adapter 22 and rotatably inserted into the center slot 210 of the valve switcher 21.

The resilient element 32, which is a compression spring, is adapted for applying an urging force against the gas adapter 22 to push it upwardly wherein the resilient element 32 has two ends biasing against a base of the central shaft 31 and a bottom surface of the gas adapter 22. Accordingly, the resilient element 32 normally urges and retains the gas adapter 22 in a higher position that the top surface of the gas adapter 22 is tightly contacted with a bottom surface of the valve switcher 21, so as to ensure the gas emitter 23 sealedly aligned with the respective gas nozzle 211 for gas transmitting therebetween.

In order to operate the interchangeable piezoelectric lighter, a user is able to select a type of flame by rotating the valve switcher 21 until the respective gas nozzle 211 is aligned with the gas emitter 23. Then, a downward force must be applied on the ignition button 15 to compress the piezoelectric unit 14 to ignite the piezoelectric lighter of the present invention, as the same as the ignition of the conventional lighter. So, the user does not have to manipulate any part of the lighter to select the flame during the ignition process, which is advantageous in practical use. Thus, for safety purpose, the gas is released from the gas valve 13 which is actuated by the ignition button 15 such that when the downward force is released on the ignition button 15, the gas valve 13 is shut off for preventing the gas releasing accidentally.

Fig. 4 illustrates an alternative mode of the flame interchanging means 20' wherein the valve switcher 21' movably received in the switcher cavity 12' in a horizontally movable manner and arranged to be movably supported on the gas adapter 22'. The valve switcher 21' comprises two gas nozzles 211' which are a visible nozzle

211a' and a torch flame 211b' parallelly provided on the valve switcher 21' respectively, so as to selectively align with the gas emitter 23'. Each of the two gas nozzles 211' has a nozzle head 213' appearing from a ceiling of the valve switcher 21' and a gas inlet 212' provided on a bottom surface of the valve switcher 21' and adapted for sealedly aligning with the gas releasing end of the gas emitter 23' such that the releasing gas is adapted for transmitting from the gas valve 13' to the respective gas nozzle 211' through the gas emitter.

Accordingly, the valve switcher 21' has an elongated guiding slot 210' transversely formed on the bottom surface thereof wherein a head portion of the central shaft 31' of the supporting frame 30' is fitted into the elongated slot 210' in such a manner that the valve switcher 21' is adapted for slidably moving on the gas adapted 22' in a horizontally movable manner. Thus, the guiding slot 210' has a predetermined length adapted for each of the gas nozzles 211' coaxially aligning with the gas emitter 23' and for reinforcing the displacement of the valve switcher 21' so as to prevent the valve switcher 21' departing from the gas adapter 22' when the valve switcher 21' is being pushed.

So, the user is able to select the type of flame by pushing the valve switcher 21' horizontally so as to line up the one of the gas nozzles 211' to the gas emitter 23'. Then the user can simply ignite the piezoelectric lighter of the present invention by pressing the ignition button 15' downwardly as the conventional lighter.

What is Claimed is:

1. An interchangeable piezoelectric lighter, comprising:

a casing receiving a liquefied gas storage and having a switcher cavity provided therein;

a gas valve operatively extended from said liquefied gas storage for controlling a flow of gas;

a piezoelectric unit fitted in said casing for generating piezoelectricity;

an ignition button mounted to said casing in a movable manner, wherein said ignition button is arranged to compress said piezoelectric unit when said ignition button is depressed; and

a flame interchanging means for selectively interchanging a flame of said piezoelectric lighter, comprising a valve switcher movably received in said switcher cavity, wherein said valve switcher comprises at least two gas nozzles selectively and coaxially aligning with said gas valve for said flow of gas passing therethrough so as to produce different flames.

2. An interchangeable piezoelectric lighter. as recited in claim 1, wherein said flame interchangeable means further comprises a gas adapter fitted in said switcher cavity wherein said valve switcher is supported on said gas adapter and a gas emitter having an inlet end operatively extended from said gas valve and a gas releasing end penetrated through said gas adapter so as to selectively align with one of said gas nozzles.

3. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said valve switcher, which is adapted for coaxially rotating with respect to said gas adapter, comprises three gas nozzles which are a which are a visible gas nozzle, a torch nozzle, and a windproof nozzle axially provided on said valve switcher respectively, so as to selectively align with said gas emitter, each of said three gas nozzles having a nozzle head appearing from a ceiling of said valve switcher and a gas inlet provided on a

bottom surface of said valve switcher and adapted for sealedly aligning with said gas releasing end of said gas emitter.

4. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

5. An interchangeable piezoelectric lighter, as recited in claim 3, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

6. An interchangeable piezoelectric lighter, as recited in claim 2, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

7. An interchangeable piezoelectric lighter, as recited in claim 3, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

8. An interchangeable piezoelectric lighter, as recited in claim 5, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

9. An interchangeable piezoelectric lighter, as recited in claim 6, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

10. An interchangeable piezoelectric lighter, as recited in claim 7, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

11. An interchangeable piezoelectric lighter, as recited in claim 8, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

12. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said valve switcher, which is movably supported on said gas adapter in a horizontally movable manner, comprises two gas nozzles which are a visible nozzle and a torch flame

parallelly provided on said switcher respectively, so as to selectively align with said gas emitter, each of said two gas nozzles having a nozzle head appearing from a ceiling of said valve switcher and a gas inlet provided on a bottom surface of said valve switcher and adapted for sealedly aligning with said gas releasing end of said gas emitter.

13. An interchangeable piezoelectric lighter, as recited in claim 12, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

14. An interchangeable piezoelectric lighter, as recited in claim 12, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has an elongated guiding slot transversely formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and slidably inserted into said guiding slot of said valve switcher.

15. An interchangeable piezoelectric lighter, as recited in claim 13, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has an elongated guiding slot transversely formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and slidably inserted into said guiding slot of said valve switcher.

16. An interchangeable piezoelectric lighter, as recited in claim 14, wherein said has a predetermined length adapted for each of said gas nozzles coaxially aligning with said gas emitter and for reinforcing a displacement of said valve switcher.

17. An interchangeable piezoelectric lighter, as recited in claim 15, wherein said has a predetermined length adapted for each of said gas nozzles coaxially aligning with said gas emitter and for reinforcing a displacement of said valve switcher.

18. An interchangeable piezoelectric lighter, as recited in claim 14, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

19. An interchangeable piezoelectric lighter, as recited in claim 15, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

20. An interchangeable piezoelectric lighter, as recited in claim 17, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

Interchangeable Piezoelectric Lighter

Abstract of the Disclosure

An interchangeable piezoelectric lighter includes a casing having a switcher cavity and a valve switcher rotatably received in the switcher cavity wherein the valve switcher includes at least two gas nozzles axially provided therein. The gas nozzles are adapted for selectively and coaxially aligning with a gas valve for producing different types flames. Therefore, by rotatably switching the valve switcher, the gas valve is adapted to align with the respective gas nozzle for a releasing gas passing therethrough, so as to produce a desired type of flame.

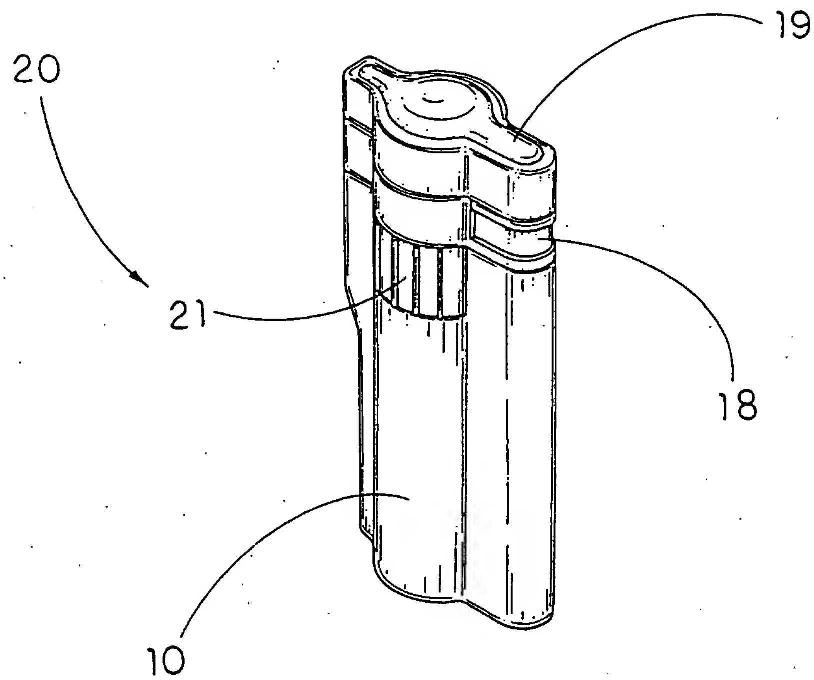

FIG.1

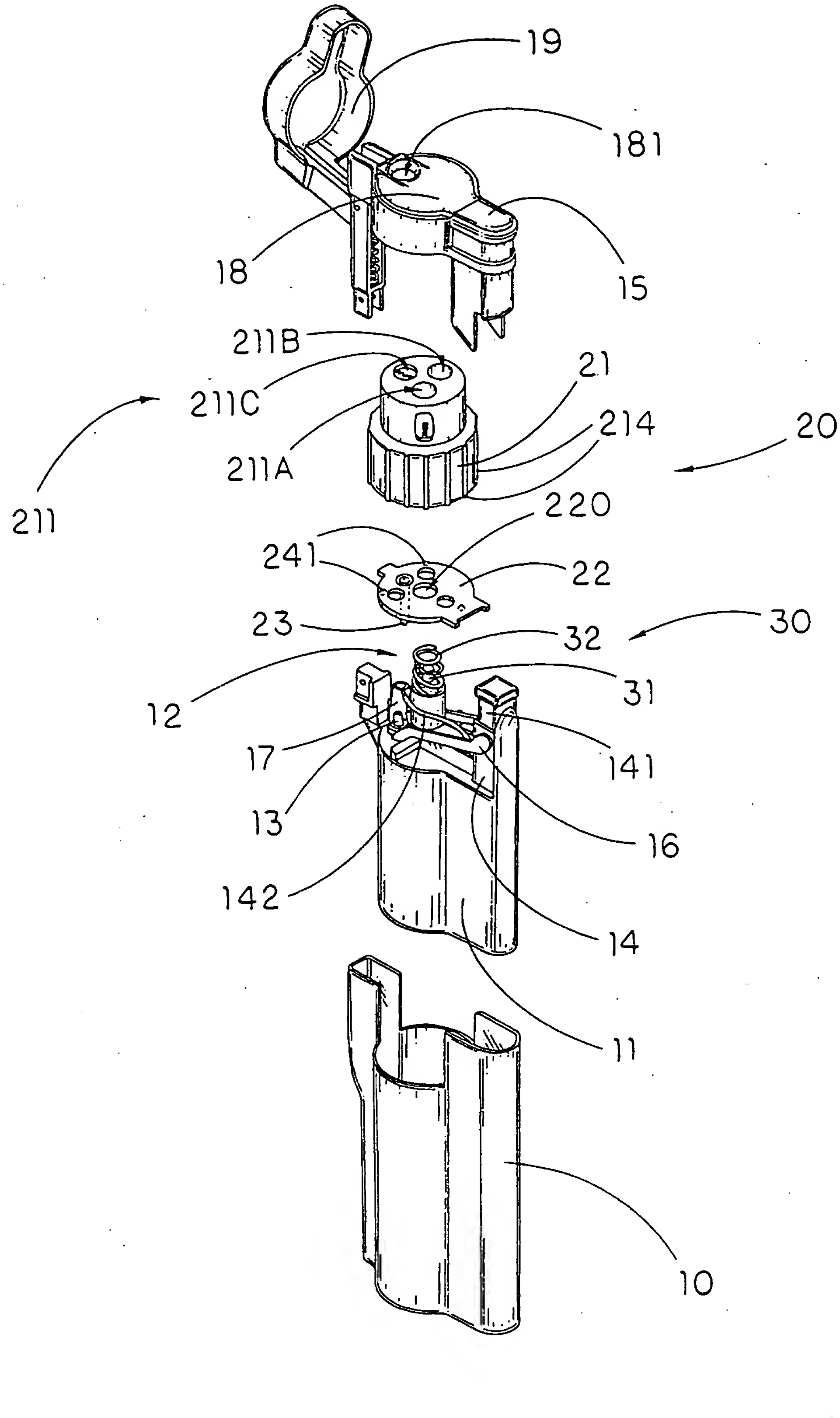
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FIG. 2

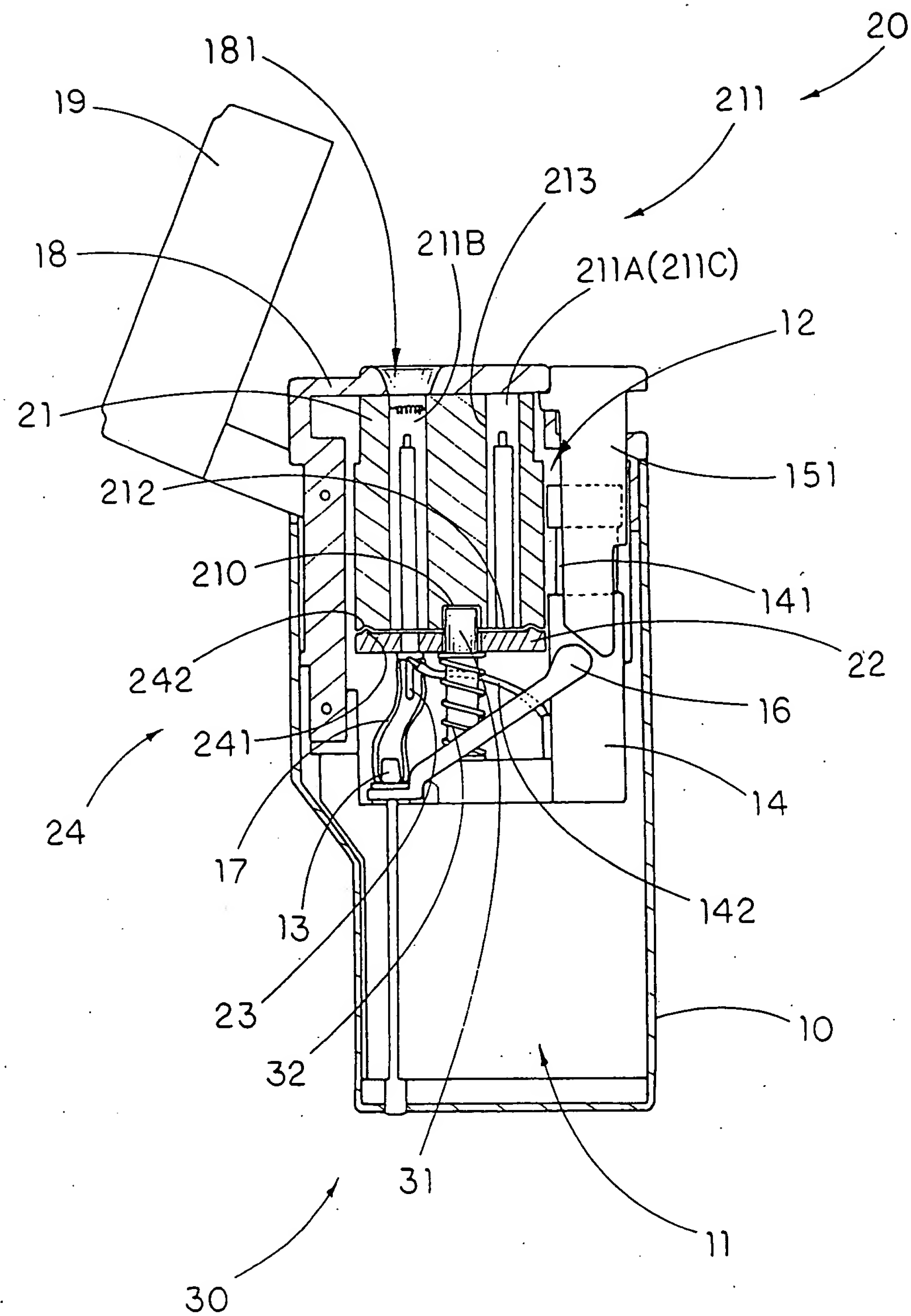
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FIG.3

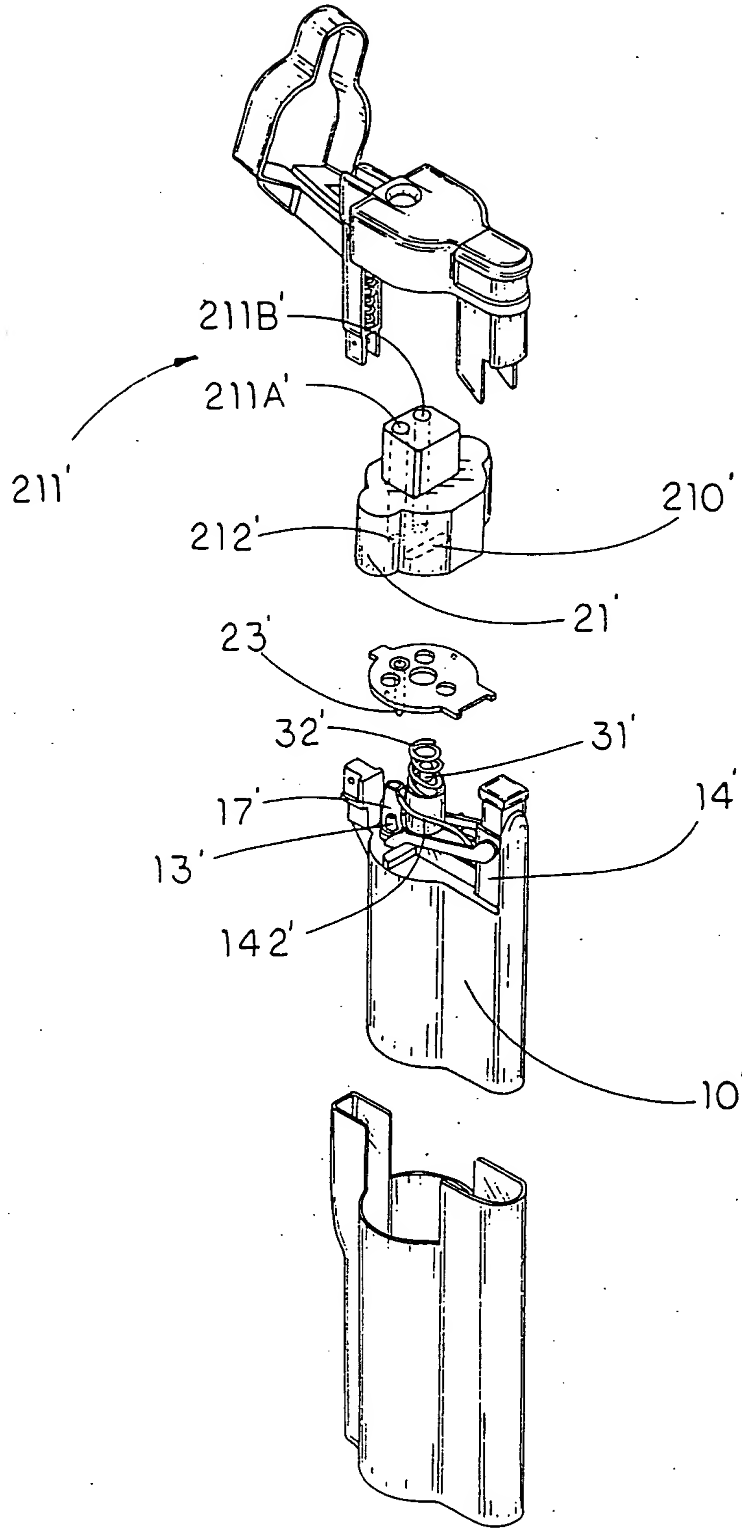

FIG.4

USP1468.1 ~~A~~ MWL

THE FOLLOWING ARE RECEIVED TODAY:

RE.: **PATENT APPLICATION**
APPLICANT: **Ming King WONG**
TITLE: **Interchangable Piezoelectric Lighter**
SPECIFICATION, CLAIMS, ABSTRACT: NO. SHEET(S): 13
DRAWING: NO. SHEET(S): 4
DECLARATION: DATE SIGNED:
Verification of Small Entity Status of applicant
Assignment

09/840,426

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09/840426
04/20/01

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Wong (43) Pub. Date: Oct. 24, 2002

(54) INTERCHANGEABLE PIEZOELECTRIC LIGHTER

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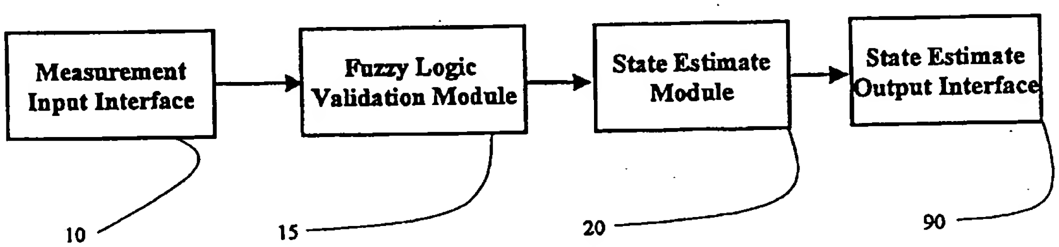
(52) U.S. Cl. 431/255

(57) ABSTRACT

An interchangeable piezoelectric lighter includes a casing having a switcher cavity and a valve switcher rotatably received in the switcher cavity wherein the valve switcher includes at least two gas nozzles axially provided therein. The gas nozzles are adapted for selectively and coaxially aligning with a gas valve for producing different types flames. Therefore, by rotatably switching the valve switcher, the gas valve is adapted to align with the respective gas nozzle for a releasing gas passing therethrough, so as to produce a desired type of flame.



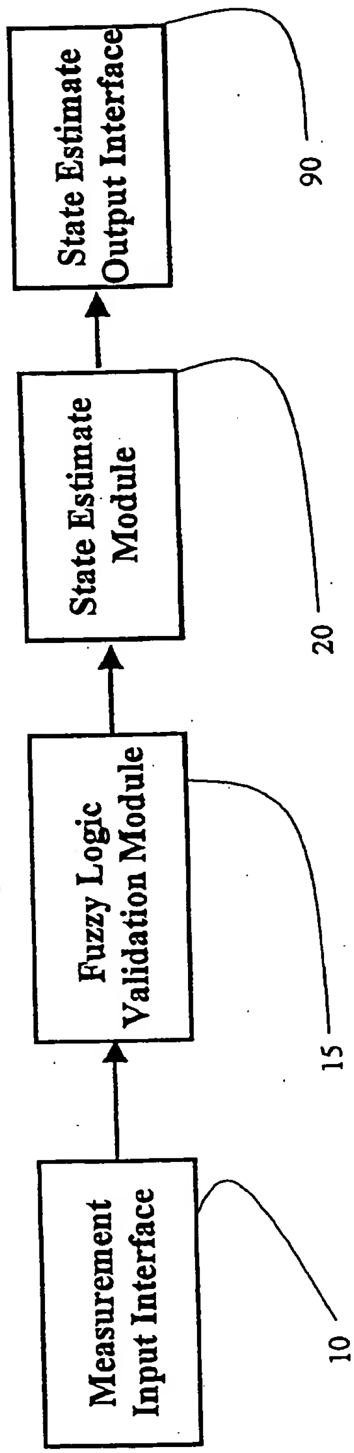

Measurement Input Interface
10
Fuzzy Logic Validation Module
15
State Estimate Module
20
State Estimate Output Interface
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FIG. 1

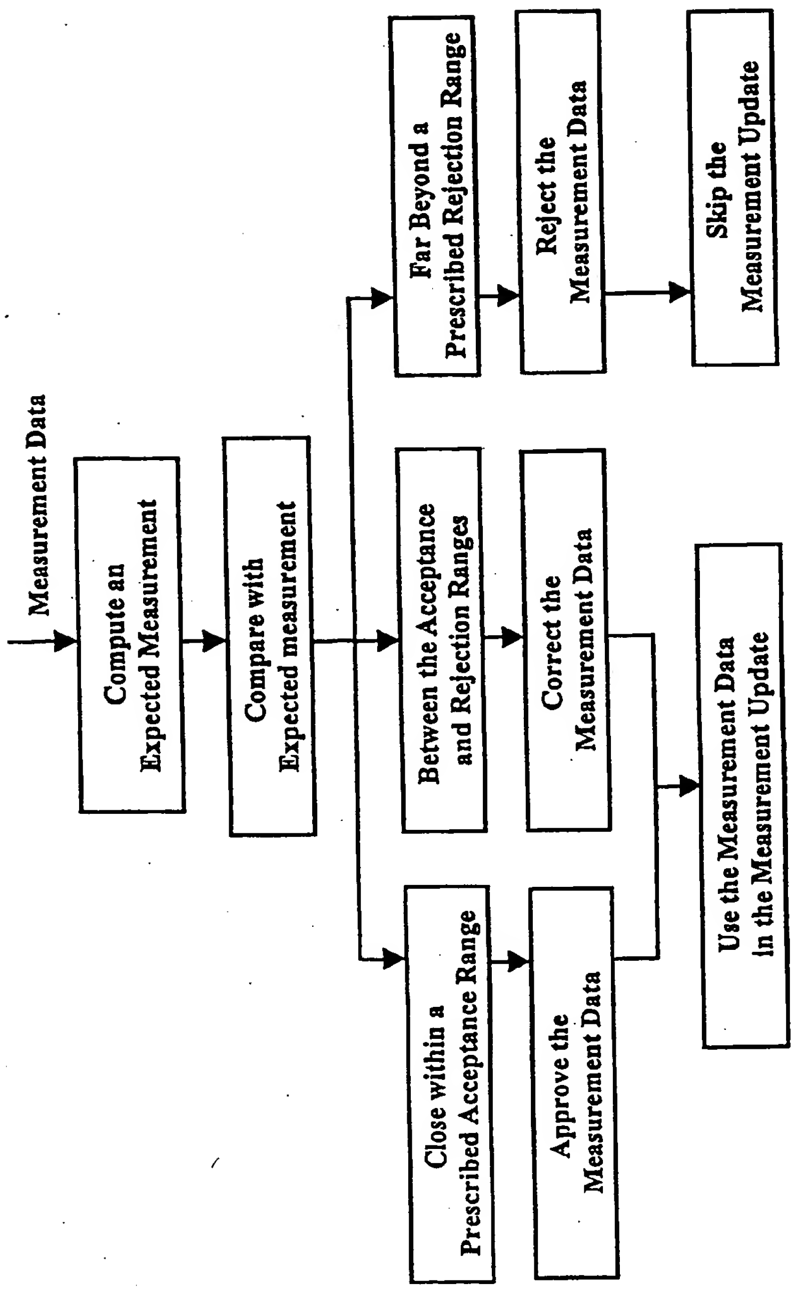
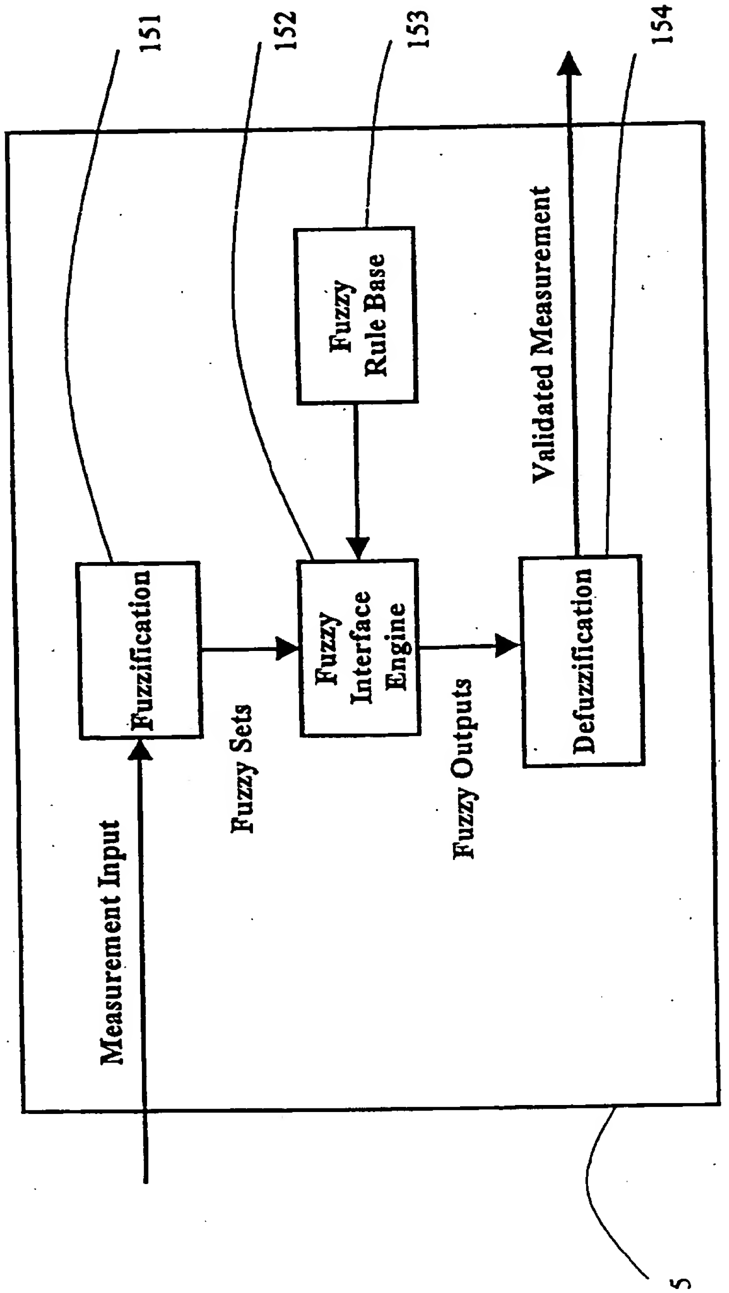

Measurement Data
Compute an Expected Measurement
Compare with Expected measurement
Far Beyond a Prescribed Rejection Range
Between the Acceptance and Rejection Ranges
Close within a Prescribed Acceptance Range
Reject the Measurement Data
Correct the Measurement Data
Approve the Measurement Data
Skip the Measurement Update
Use the Measurement Data in the Measurement Update

FIG. 2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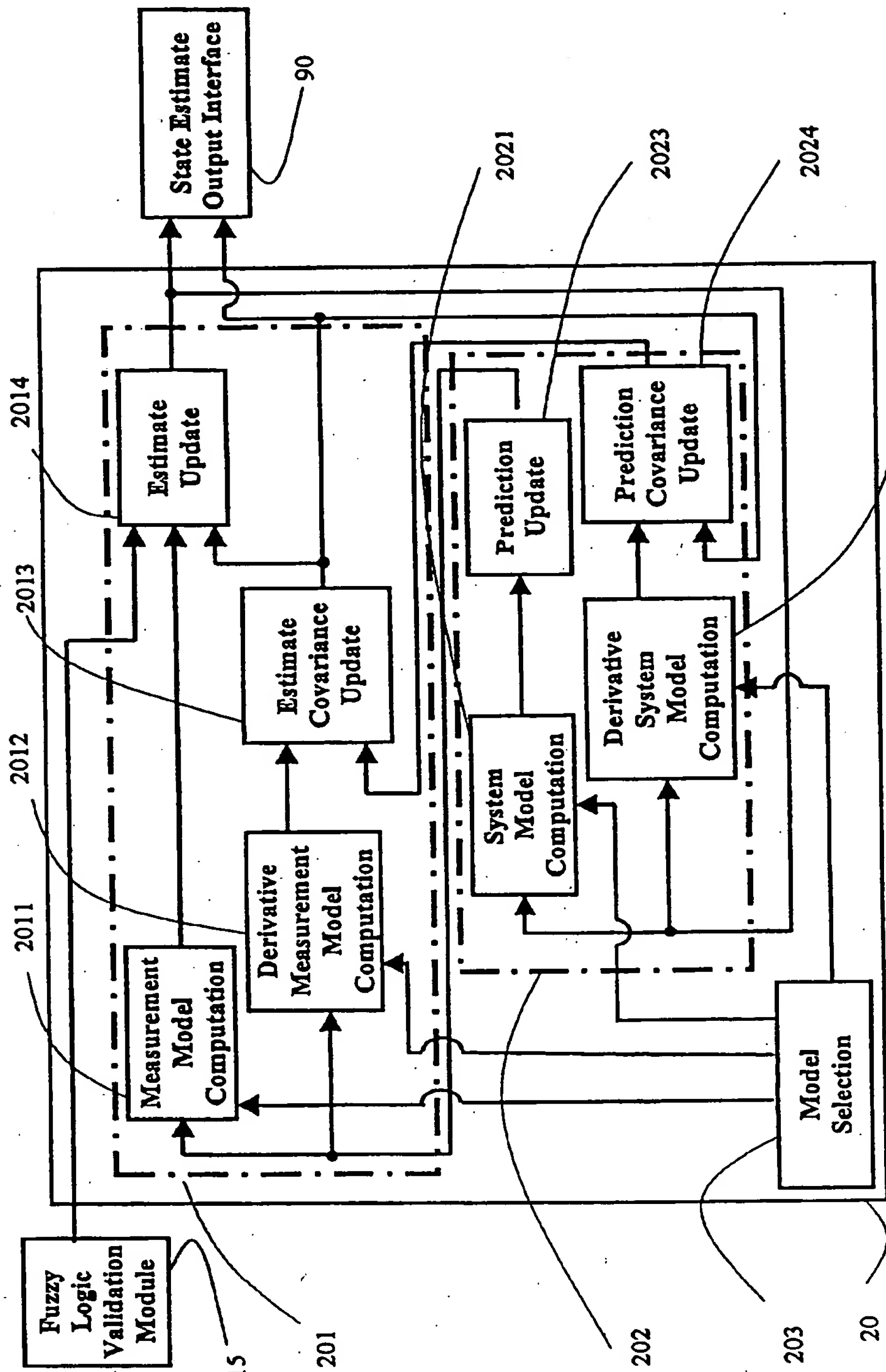
Validated Measurement
Fuzzification
Fuzzy Interface Engine
Defuzzification
Measurement Input
Fuzzy Sets
Fuzzy Outputs
15

FIG. 3


State Estimate Output Interface
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2021
2023
2024
2022
2014
Estimate Update
2013
Estimate Covariance Update
2012
Derivative Measurement Model Computation
2011
Measurement Model Computation
Prediction Update
Prediction Covariance Update
System Model Computation
Derivative System Model Computation
Model Selection
Fuzzy Logic Validation Module
15
201
202
203
20

FIG. 4

INTERCHANGEABLE PIEZOELECTRIC LIGHTER

BACKGROUND OF THE PRESENT INVENTION

[0001] 1. Field of Invention

[0002] The present invention relates to piezoelectric lighters, and more particularly to an interchangeable piezoelectric lighter which is adapted for selectively interchanging a type of flame between a visible flame, a torch flame, and a windproof flame.

[0003] 2. Description of Related Arts

[0004] Piezoelectric lighters have been known and sold throughout the United States. The conventional piezoelectric lighters are generally classified into two categories which is the visible flame type piezoelectric lighter and the torch flame type piezoelectric lighter. The visible flame type piezoelectric lighter, such as a cigarette lighter, allows gas emitted from the nozzle directly burned in the air to produce a regular visible flame. A windproof type piezoelectric lighter, has a re-igniting properties wherein an ignition element is heated up when igniting the lighter in such a manner that once the flame is blown out, the ignition element remains in high temperature and re-ignites the emitted gas to regain the flame. Thus, a torch lighter is adapted for providing a high temperature torch flame wherein the torch flame is more powerful than the visible flame so as to increase the burning purpose of the lighter.

[0005] For smokers, especially cigar and pipe smokers, do not ready like to use the torch flame type piezoelectric lighter since the high temperature torch flame will destroy the taste of the tobacco. However, it is a hassle for the smoker to light a cigarette or a cigar outdoors while using the visible flame type piezoelectric lighter. Thus, it is inconvenient for the smokers to carry different types of lighter at once.

[0006] Moreover, an improved piezoelectric lighter is adapted for selecting the flame by manipulating an ignition button wherein when a downward force is applied on the ignition button to depress the ignition button, such lighter provides a torch flame and when the downward force is released, the lighter provides a visible flame. However, a user must manipulate the ignition button and leads to different operational results depending on the user, which may be considered disadvantageous in practical use. Thus, the lighter must require other parts to incorporate therewith for controlling a flow of gas. Generally, a lighter cap is incorporated with the lighter for actuating a valve thereof such that when the lighter cap is opened, the gas is released from the gas chamber through the valve. This adverse result affects the ease of leaking the gas from the gas chamber. So, such improved lighter still has drawbacks in practical use and hence there has been a demand for an interchangeable lighter which is improved in both safety and operability.

SUMMARY OF THE PRESENT INVENTION

[0007] A main object of the present invention is to provide an interchangeable piezoelectric lighter which is adapted for selectively interchanging a type of flame between a visible flame, torch flame, and a windproof flame.

[0008] Another object of the present invention is to provide an interchangeable piezoelectric lighter which produces both visible flame, windproof flame, and torch flame for selectively lighting a cigarette, cigar and pipe conveniently.

[0009] Another object of the present invention is to provide an interchangeable piezoelectric lighter wherein the visible flame, the torch flame, and the windproof flame are selectively produced by controlling a flame interchanging means such that no mechanism is required for users to manipulate in order to select the flame such as the ignition button.

[0010] Another object of the present invention is to provide an interchangeable piezoelectric lighter wherein the l ighter is improved in both safety and operability. A user selects a desired flame by manipulating the flame interchanging means and then ignites the lighter in one single action, which is advantageous in practical use.

[0011] Accordingly, in order to accomplish the above objects, the present invention provides an interchangeable piezoelectric lighter, comprising:

[0012] a casing receiving a liquefied gas storage and a switcher cavity provided therein;

[0013] a gas valve operatively extended from the liquefied gas storage for controlling a flow of gas;

[0014] a piezoelectric unit fitted in the casing for generating piezoelectricity;

[0015] an ignition button slidably fitted in the casing in a vertically movable manner wherein the ignition button is attached to a top end of the piezoelectric unit and arranged to compress the piezoelectric unit when the ignition button is depressed; and

[0016] a flame interchanging means for selectively interchanging a flame of the piezoelectric lighter, comprising a valve switcher movably received in the switcher cavity wherein the valve switcher comprises at least two gas nozzles selectively and coaxially aligning with the gas valve for the flow of gas passing therethrough so as to produce different flames.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 is a perspective view of an interchangeable piezoelectric lighter according to a preferred embodiment of the present invention.

[0018] FIG. 2 is an exploded perspective view of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

[0019] FIG. 3 is a sectional view of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

[0020] FIG. 4 illustrates an alternative mode of a flame interchanging means of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0021] Referring to FIGS. 1 to 3 of the drawings, an interchangeable piezoelectric lighter according to a preferred embodiment of the present invention is illustrated.

The interchangeable piezoelectric lighter, such as a standard piezoelectric lighter, comprises a casing 10 receiving a liquefied gas storage 11 and a switcher cavity 12 provided therein, a gas valve 13 operatively extended from the liquefied gas storage 11 for controlling a flow of gas, a piezoelectric unit 14 fitted in the casing 10 for generating piezoelectricity, and an ignition button 15 slidably fitted in the casing 10 in a vertically movable manner.

[0022] The piezoelectric unit 14, which is disposed in the casing 10, comprises a movable operating part 141 extended upwardly and an ignition tip 142 extended to a position towards to the gas valve 13, wherein when the movable operating part 141 is depressed downwardly, the ignition tip 142 generates sparks to ignite the gas emitted from the gas valve 13 at the same time.

[0023] The ignition button 15 is attached to a top end of the movable operating part 141 of the piezoelectric unit 13 and operatively connected to the gas valve 13 via a gas lever 16. Accordingly, when the ignition button 15 is pushed downward, the movable operating part 141 of the piezoelectric unit 14 is compressed for generating piezoelectricity through and out the ignition tip 142. At the same time, the gas lever 16 is simultaneously pressed by the ignition button 15 to release gas through the gas valve 13 so as to ignite the releasing gas by the spark from the ignition tip 142.

[0024] The interchangeable piezoelectric lighter further comprises a flame interchanging means 20 for selectively interchanging a flame of the piezoelectric lighter, comprising a valve switcher 21 movably received in the switcher cavity 12 in a rotatably movable manner wherein the valve switcher 21 comprises at least two gas nozzles 211 selectively and coaxially aligning with the gas valve 13 for the flow of gas passing therethrough so as to produce different flames.

[0025] The valve switcher 21 has a lower portion exposed to an exterior of the casing 10 wherein a plurality of flanges 214 are spacedly protruded on an outer circumferential surface of the lower portion of the valve switcher 21 for being rotated easily and an upper portion rotatably received in a cover 18 which is supported on the casing 10. The cover 18 has a through hole 181 provided thereon and arranged to align with gas valve 13 for the flame passing through. Thus, a cap 19 is pivotally mounted on the cover 18 for protecting the valve nozzle 211.

[0026] The flame interchanging means 20 further comprises a gas adapter 22 fitted in the switcher cavity 12 wherein the valve switcher 21 is supported thereon and a gas emitter 22, made of conductive material, having an inlet end operatively extended from the gas valve 13 and a gas releasing end penetrated through the gas adapter 22 so as to selectively align with one of the gas nozzles 211, 212.

[0027] According to the preferred embodiment, the valve switcher 21 having a circular shaped rotatably and sealedly mounted on the gas adapter 22 wherein the valve switcher 21 comprises three gas nozzles 211, which are a visible gas nozzle 211*a*, a torch nozzle 211*b*, and a windproof nozzle 211*c*, axially provided on the valve switcher 21 respectively, so as to selectively align with the gas emitter 23. Each of the three gas nozzles 211 has a nozzle head 213 appearing from a ceiling of the valve switcher 21 and a gas inlet 212 provided on a bottom surface of the valve switcher 21 and adapted for sealedly aligning with the gas releasing end of the gas emitter 23 such that the releasing gas is adapted for transmitting from the gas valve 13 to the respective gas nozzle 211 through the gas emitter 23, as shown in FIG. 3.

[0028] Accordingly, a gas conduit 17, which is made of non-conductive material such as plastic, is connected between the gas valve 13 and the gas emitter 23 wherein the ignition tip 142 is extended to a position close to the gas emitter 23 in such a manner that the piezoelectricity generated by the piezoelectric unit 14 is transmitted to the gas emitter 23 by conduction for igniting the releasing gas from the gas valve 13. However, the piezoelectricity cannot transmit to the gas valve 13 through the gas conduit 17 because the gas conduit 17 functions as a resistance for resisting the piezoelectricity transmitting therethrough.

[0029] The flame interchanging means 20 further comprises a guiding unit 24 for guiding the gas emitter 23 aligned with the respective gas nozzle 211 wherein the guiding unit 24 comprises at least a protrusion 241 upwardly provided on a top surface of the gas adapter 22 and at least a corresponding indention 242 formed on a bottom surface of the valve switcher 21 in such a manner that the protrusion 241 is fittedly engaged with the indention 242 when the gas emitter 23 is aligned with the respective gas nozzle 211, so as to ensure the alignment thereof.

[0030] The interchangeable piezoelectric lighter further comprises a supporting frame 30 comprising a central shaft 31 upwardly extended from the switcher cavity 12 wherein the valve switcher 21 is rotatably supported by the central shaft 31 and a resilient element 32 coaxially mounted on the central shaft 31 for applying an urging force against the gas adapter 22.

[0031] Accordingly, the valve switcher 21 has a center slot 210 coaxially formed on a bottom surface thereof and the gas adapter 22 has a center through hole 220 coaxially formed thereon in such a manner that the central shaft 31 is penetrated through the center through hole 220 of the gas adapter 22 and rotatably inserted into the center slot 210 of the valve switcher 21.

[0032] The resilient element 32, which is a compression spring, is adapted for applying an urging force against the gas adapter 22 to push it upwardly wherein the resilient element 32 has two ends biasing against a base of the central shaft 31 and a bottom surface of the gas adapter 22. Accordingly, the resilient element 32 normally urges and retains the gas adapter 22 in a higher position that the top surface of the gas adapter 22 is tightly contacted with a bottom surface of the valve switcher 21, so as to ensure the gas emitter 23 sealedly aligned with the respective gas nozzle 211 for gas transmitting therebetween.

[0033] In order to operate the interchangeable piezoelectric lighter, a user is able to select a type of flame by rotating the valve switcher 21 until the respective gas nozzle 211 is aligned with the gas emitter 23. Then, a downward force must be applied on the ignition button 15 to compress the piezoelectric unit 14 to ignite the piezoelectric lighter of the present invention, as the same as the ignition of the conventional lighter. So, the user does not have to manipulate any part of the lighter to select the flame during the ignition process, which is advantageous in practical use. Thus, for safety purpose, the gas is released from the gas valve 13

which is actuated by the ignition button 15 such that when the downward force is released on the ignition button 15, the gas valve 13 is shut off for preventing the gas releasing accidentally.

[0034] FIG. 4 illustrates an alternative mode of the flame interchanging means 20' wherein the valve switcher 21' movably received in the switcher cavity 12' in a horizontally movable manner and arranged to be movably supported on the gas adapter 22'. The valve switcher 21' comprises two gas nozzles 211' which are a visible nozzle 211*a*' and a torch flame 211*b*' parallelly provided on the valve switcher 21' respectively, so as to selectively align with the gas emitter 23'. Each of the two gas nozzles 211' has a nozzle head 213' appearing from a ceiling of the valve switcher 21' and a gas inlet 212' provided on a bottom surface of the valve switcher 21' and adapted for sealedly aligning with the gas releasing end of the gas emitter 23' such that the releasing gas is adapted for transmitting from the gas valve 13' to the respective gas nozzle 211' through the gas emitter.

[0035] Accordingly, the valve switcher 21' has an elongated guiding slot 210' transversely formed on the bottom surface thereof wherein a head portion of the central shaft 31' of the supporting frame 30' is fitted into the elongated slot 210' in such a manner that the valve switcher 21' is adapted for slidably moving on the gas adapted 22' in a horizontally movable manner. Thus, the guiding slot 210' has a predetermined length adapted for each of the gas nozzles 211' coaxially aligning with the gas emitter 23' and for reinforcing the displacement of the valve switcher 21' so as to prevent the valve switcher 21' departing from the gas adapter 22' when the valve switcher 21' is being pushed.

[0036] So, the user is able to select the type of flame by pushing the valve switcher 21' horizontally so as to line up the one of the gas nozzles 211' to the gas emitter 23'. Then the user can simply ignite the piezoelectric lighter of the present invention by pressing the ignition button 15' downwardly as the conventional lighter.

What is claimed is:

1. An interchangeable piezoelectric lighter, comprising:

a casing receiving a liquefied gas storage and having a switcher cavity provided therein;

a gas valve operatively extended from said liquefied gas storage for controlling a flow of gas;

a piezoelectric unit fitted in said casing for generating piezoelectricity;

an ignition button mounted to said casing in a movable manner, wherein said ignition button is arranged to compress said piezoelectric unit when said ignition button is depressed; and

a flame interchanging means for selectively interchanging a flame of said piezoelectric lighter, comprising a valve switcher movably received in said switcher cavity, wherein said valve switcher comprises at least two gas nozzles selectively and coaxially aligning with said gas valve for said flow of gas passing therethrough so as to produce different flames.

2. An interchangeable piezoelectric lighter as recited in claim 1, wherein said flame interchangeable means further comprises a gas adapter fitted in said switcher cavity wherein said valve switcher is supported on said gas adapter and a gas emitter having an inlet end operatively extended from said gas valve and a gas releasing end penetrated through said gas adapter so as to selectively align with one of said gas nozzles.

3. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said valve switcher, which is adapted for coaxially rotating with respect to said gas adapter, comprises three gas nozzles which are a which are a visible gas nozzle, a torch nozzle, and a windproof nozzle axially provided on said valve switcher respectively, so as to selectively align with said gas emitter, each of said three gas nozzles having a nozzle head appearing from a ceiling of said valve switcher and a gas inlet provided on a bottom surface of said valve switcher and adapted for sealedly aligning with said gas releasing end of said gas emitter.

4. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

5. An interchangeable piezoelectric lighter, as recited in claim 3, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

6. An interchangeable piezoelectric lighter, as recited in claim 2, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

7. An interchangeable piezoelectric lighter, as recited in claim 3, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

8. An interchangeable piezoelectric lighter, as recited in claim 5, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying

an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

9. An interchangeable piezoelectric lighter, as recited in claim 6, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

10. An interchangeable piezoelectric lighter, as recited in claim 7, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

11. An interchangeable piezoelectric lighter, as recited in claim 8, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

12. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said valve switcher, which is movably supported on said gas adapter in a horizontally movable manner, comprises two gas nozzles which are a visible nozzle and a torch flame parallelly provided on said switcher respectively, so as to selectively align with said gas emitter, each of said two gas nozzles having a nozzle head appearing from a ceiling of said valve switcher and a gas inlet provided on a bottom surface of said valve switcher and adapted for sealedly aligning with said gas releasing end of said gas emitter.

13. An interchangeable piezoelectric lighter, as recited in claim 12, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

14. An interchangeable piezoelectric lighter, as recited in claim 12, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has an elongated guiding slot transversely formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and slidably inserted into said guiding slot of said valve switcher.

15. An interchangeable piezoelectric lighter, as recited in claim 13, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has an elongated guiding slot transversely formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and slidably inserted into said guiding slot of said valve switcher.

16. An interchangeable piezoelectric lighter, as recited in claim 14, wherein said has a predetermined length adapted for each of said gas nozzles coaxially aligning with said gas emitter and for reinforcing a displacement of said valve switcher.

17. An interchangeable piezoelectric lighter, as recited in claim 15, wherein said has a predetermined length adapted for each of said gas nozzles coaxially aligning with said gas emitter and for reinforcing a displacement of said valve switcher.

18. An interchangeable piezoelectric lighter, as recited in claim 14, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

19. An interchangeable piezoelectric lighter, as recited in claim 15, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

20. An interchangeable piezoelectric lighter, as recited in claim 17, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

* * * * *

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Lin

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(45) Date of Patent: *Jun. 29, 2004

(54) FILTERING PROCESS FOR STABLE AND ACCURATE ESTIMATION

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(73) Assignee: American GNC Corporation, Simi Valley, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: 09/840,511

(22) Filed: Apr. 20, 2001

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) Int. Cl.[7] G05B 13/02

(52) U.S. Cl. 700/29; 700/700; 700/50; 700/55; 700/52; 700/44; 706/900; 708/300; 708/303

(58) Field of Search 700/2, 55, 50, 700/52, 53, 44, 305; 706/900; 708/300, 303; 701/3, 13, 213, 214, 200, 207, 208, 226

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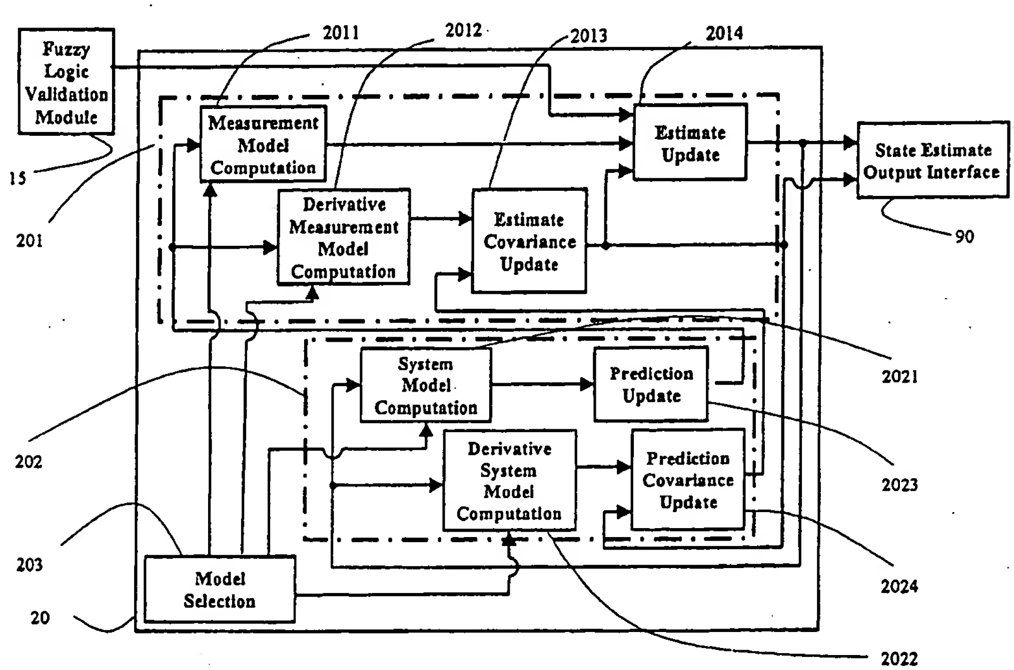
Primary Examiner—Ramesh Patel

(74) *Attorney, Agent, or Firm*—Raymond Y. Chan; David and Raymond Patent Group

(57) **ABSTRACT**

A filtering process is adapted for eliminating the need of prediscretizing a continuous-time differential model into a discrete-time difference model. It provides a universal robust solution to the most general formulation, in the sense that the system dynamics are described by nonlinear continuous-time differential equations, and the nonlinear measurements are taken at intermittent discrete times randomly spaced. The filtering process includes the procedures of validating the measurement using fuzzy logic, and incorporating factorized forward filtering and backward smoothing to guarantee numerical stability. It provides users a reliable and convenient solution to extracting internal dynamic system state estimates from noisy measurements, with wider applications, better accuracy, better stability, easier design, and easier implementation.

13 Claims, 6 Drawing Sheets



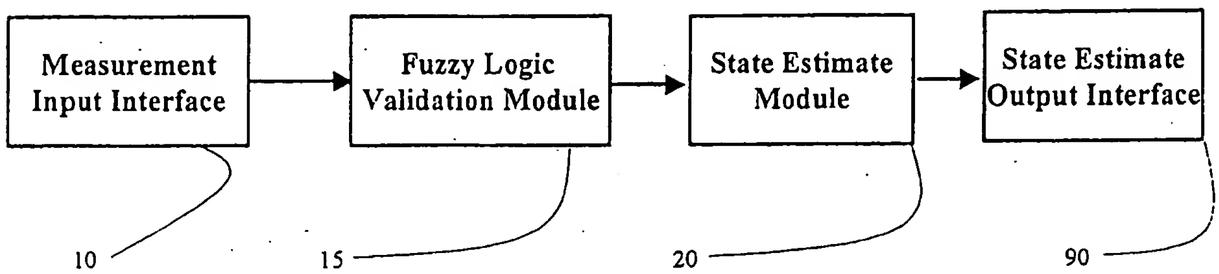

Measurement Input Interface
Fuzzy Logic Validation Module
State Estimate Module
State Estimate Output Interface
10
15
20
90

FIG. 1

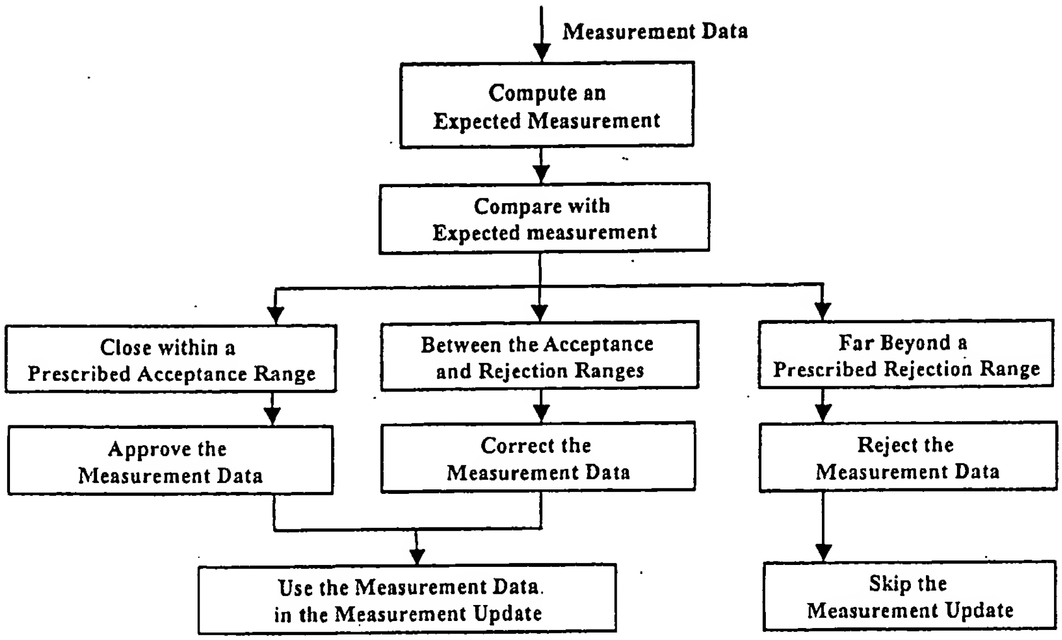

Measurement Data
Compute an Expected Measurement
Compare with Expected measurement
Close within a Prescribed Acceptance Range
Between the Acceptance and Rejection Ranges
Far Beyond a Prescribed Rejection Range
Approve the Measurement Data
Correct the Measurement Data
Reject the Measurement Data
Use the Measurement Data in the Measurement Update
Skip the Measurement Update

FIG. 2

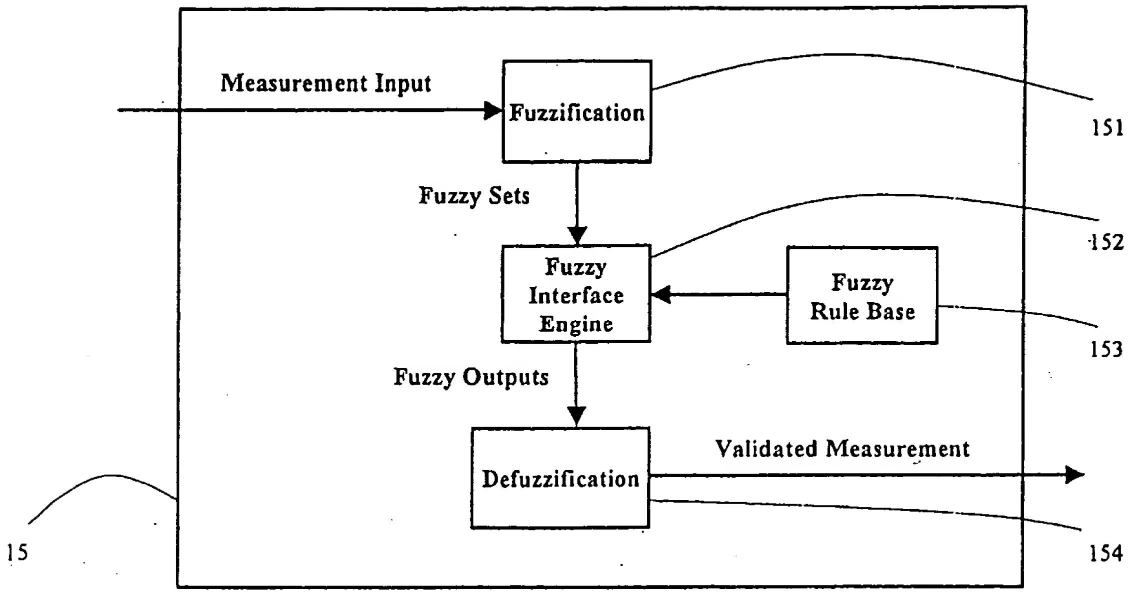

Measurement Input
Fuzzification
151
Fuzzy Sets
Fuzzy Interface Engine
152
Fuzzy Rule Base
153
Fuzzy Outputs
Defuzzification
Validated Measurement
154
15

FIG. 3

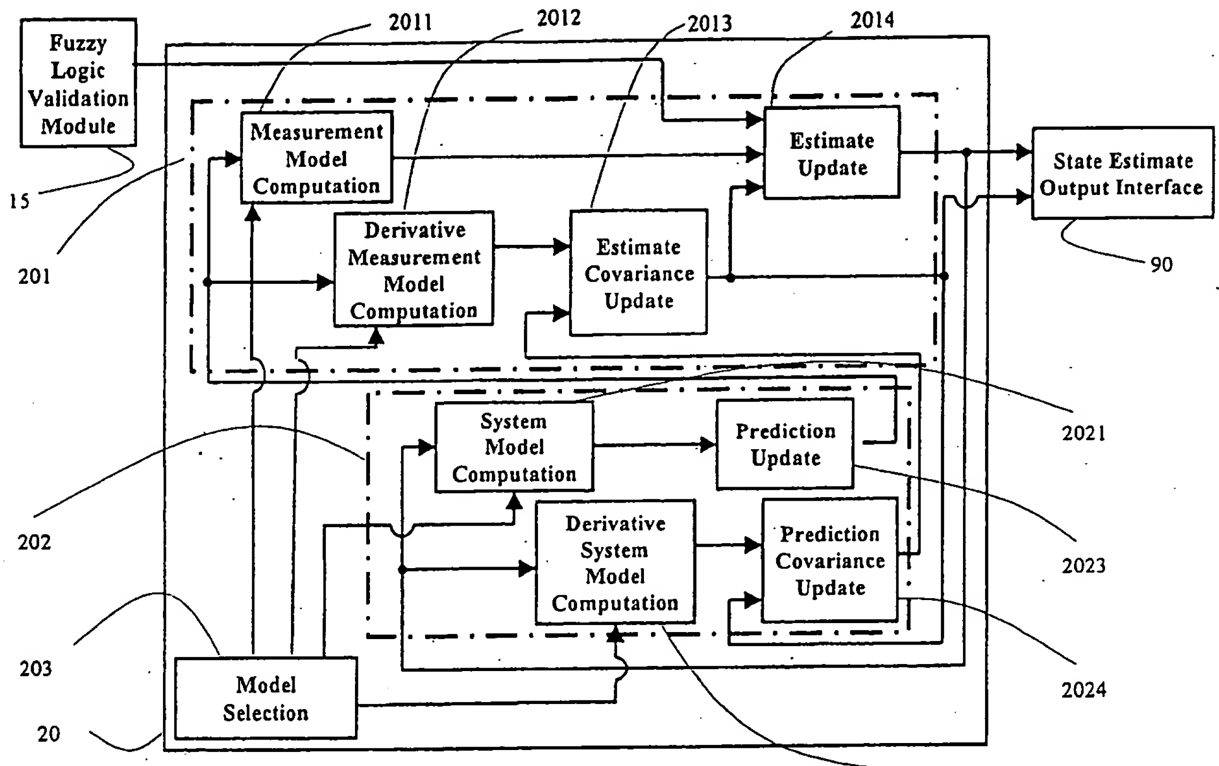

Fuzzy Logic Validation Module
15
2011
2012
2013
2014
Measurement Model Computation
Derivative Measurement Model Computation
Estimate Covariance Update
Estimate Update
State Estimate Output Interface
90
201
2021
System Model Computation
Prediction Update
202
2023
Derivative System Model Computation
Prediction Covariance Update
203
2024
Model Selection
20
2022

FIG. 4

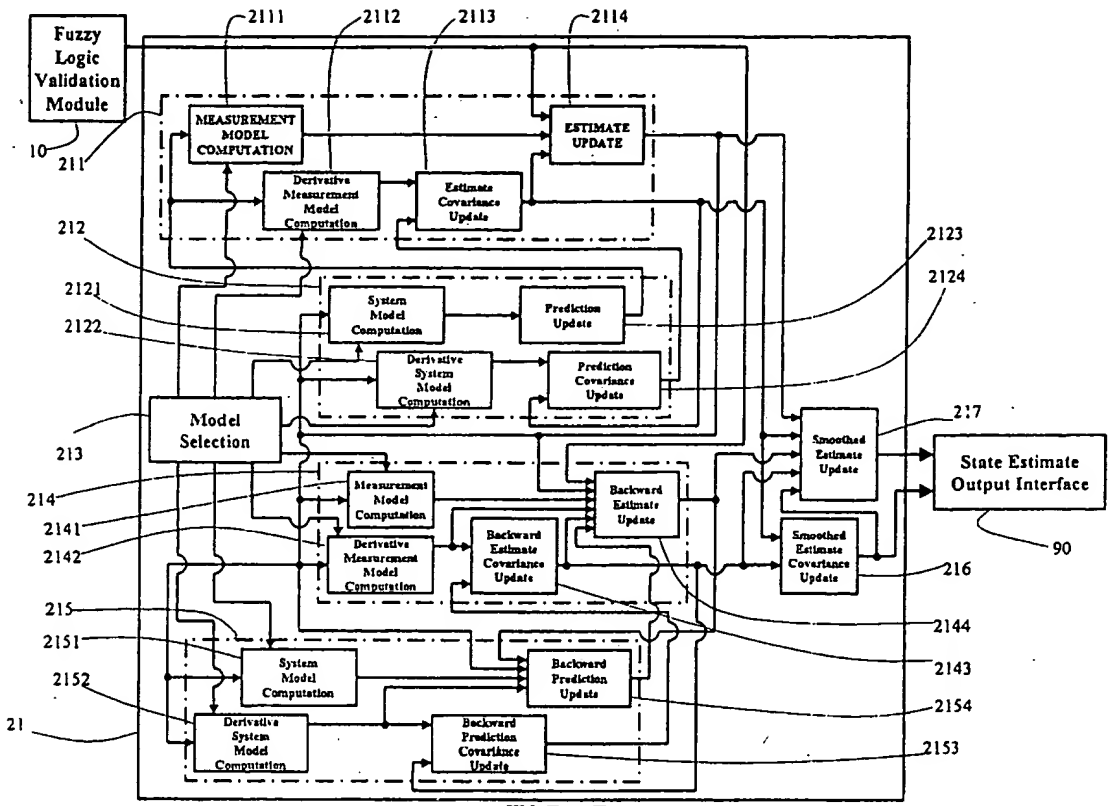

Fuzzy Logic Validation Module
10
211
2111
2112
2113
2114
MEASUREMENT MODEL COMPUTATION
ESTIMATE UPDATE
Derivative Measurement Model Computation
Estimate Covariance Update
212
2121
2122
2123
2124
System Model Computation
Prediction Update
Derivative System Model Computation
Prediction Covariance Update
213
Model Selection
214
2141
2142
Measurement Model Computation
Derivative Measurement Model Computation
Backward Estimate Covariance Update
Backward Estimate Update
Smoothed Estimate Update
Smoothed Estimate Covariance Update
State Estimate Output Interface
217
90
216
2144
2143
215
2151
2152
21
System Model Computation
Derivative System Model Computation
Backward Prediction Update
Backward Prediction Covariance Update
2154
2153

FIG. 5

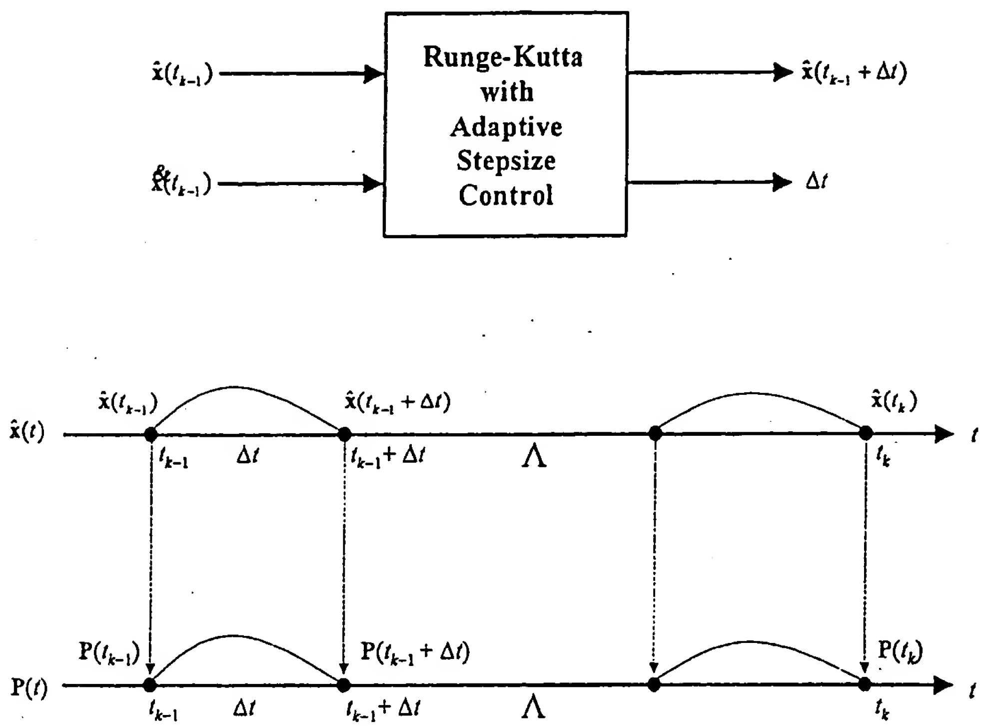

Runge-Kutta with Adaptive Stepsize Control
x̂(t_{k-1})
x̂(t_{k-1} + Δt)
Δt
x̂(t)
t_{k-1}
t_{k-1} + Δt
x̂(t_k)
t_k
t
P(t)
P(t_{k-1})
P(t_{k-1} + Δt)
P(t_k)
Λ

FIG. 6

FILTERING PROCESS FOR STABLE AND ACCURATE ESTIMATION

CROSS REFERENCE OF RELATED APPLICATION

This is a divisional application of a non-provisional application, application Ser. No. of 09/551,897, filed Apr. 19, 2000 now U.S. Pat. No. 6,510,354.

FIELD OF THE PRESENT INVENTION

The present invention relates to robust information extraction, and more particularly to a filtering process for stable and accurate estimation.

BACKGROUND OF THE PRESENT INVENTION

In most information extraction applications, propagation of an internal state of a dynamic system, which is not measurable by sensors directly, is naturally described by nonlinear continuous-time differential equations, based upon physical laws,

$$\dot{x}(t)=f(x(t))+w(t)$$

where x(t) is a state vector, f(x) is a vector nonlinear function describing the system dynamics, and w(t) is a system noise with a covariance matrix Q(t).

Measurable quantities, which are generally available at intermittent discrete times, are usually in nonlinear relationship with the internal system states,

$$z(k)=h(x(k))+v(k)$$

where z(k) represents a discrete measurement at the k-th sampling time t_k, h(x) is a vector nonlinear function which describes the relationship of the measurement with the state vector, and v(k) is a measurement noise with a covariance of R(k).

A filtering process deals with the problem of extracting the internal, sometimes hidden and unmeasurable, state, x(t), from the measurement z(k). Applications of the filtering process are very common, to name a few, such as classifying the component materials from hyperspectral imagery, obtaining the aircraft position and attitude from the accelerometer and gyro measurements of an Inertial Measurement Unit, and tracking a target's velocity and acceleration from a Radar's positional measurements.

Under the conditions of a linear system with linear measurements, a Gaussian system noise and a Gaussian measurement noise, a linear Kalman filter provides an optimal estimate of the internal system state. The estimate is optimal in the sense that the covariance of the estimate is minimal, the residuals are a white Gaussian noise process, and innovative information is absent in the residuals. If selectively, the system model and the measurement model are nonlinear, extracting an estimate of the internal system state x(t), from noisy measurements, z(k), is conventionally accomplished by an extended Kalman filter, and selectively, in some cases, by a variant of the extended Kalman filter. An extended Kalman filter shares most of the salient features with a linear Kalman filter, by linearizing the nonlinear system equations and measurement equations about the most recent estimate and taking a first-order approximation to a Taylor-series expansion.

In the nonlinear cases, an optimal estimate of the system state is difficult for the extended Kalman filter to attain. A direct implementation of an extended Kalman filter possesses several inherent drawbacks. First, it is prone to numerical divergence. The correct propagation of the state estimates relies on the proper propagation of a covariance error matrix, which must remain symmetric and positive definite all the time, due to its mathematical definition. Finite-length manipulations, such as computer roundoff error, usually result in a loss of the symmetry and positive definiteness of the covariance error matrix resulting in numerical instability. A feasible approach is unavailable to recover from such a numerical divergence status.

An extended Kalman filter passively accepts measurements and is sensitive to measurement quality. Conventionally, it accepts whatever measurement data the measurement input interface provides in full confidence. The Kalman filter is unable to distinguish good-quality measurements from low-quality ones. It generally does not attempt to correct the measurement data by any means even though there might be enough evidence that the quality of measurement data is very poor. When the quality of the measurements applied to the Kalman filter is worse than that accounted for by the measurement noise, the results generated by the Kalman filter are usually meaningless, and yet, it is difficult to determine whether the results are meaningless.

Another difficulty in a conventional extended Kalman filter is the requirement of discretizing the continuous-time differential model into a discrete-time difference model. This in turn requires the selection of a discretization time prior to the design of the extended Kalman filter. A standard method is to set the discretization time the same as the sampling period of the measurements. Such a prediscretization approach does not guarantee that the discrete-time difference model is a good approximation to the continuous-time differential model, especially in the case of a slow sampling rate. Neither is this prediscretization approach able to detect a divergence of the discrete-time difference model from the continuous-time differential model when the divergence occurs.

SUMMARY OF THE PRESENT INVENTION

An objective of the present invention is to provide a filtering process for the most general formulation, in the sense that the system dynamics are described by nonlinear continuous-time differential equations, and the nonlinear measurements are taken at intermittent discrete times randomly spaced, wherein the selection of a discretization time for the continuous-time differential model is unnecessary, which possesses wider applications, better accuracy, better stability, easier design, and easier implementation.

Another objective of the present invention is to provide a filtering process, wherein the propagation of the system state estimate between two consecutive measurement instants in the time update is governed by an adaptive stepsize control, which automatically determines the time step and guarantees the convergence.

Another objective of the present invention is to provide a filtering process, which validates measurement data, in order to reject poor-quality measurement data before they are fed into the filter.

Another objective of the present invention is to provide a filtering process, which corrects measurement data, in order to correct low-quality measurement data before they are fed into the filter.

Another objective of the present invention is to provide a filtering process, comprising an adaptive stepsize control to automatically compute the stepsize to propagate the backward state estimate in the backward time update.

Another objective of the present invention is to provide a filtering process, wherein square root implementations are enforced for covariance matrix propagation, wherever applied, to ensure numerical stability.

Another objective of the present invention is to provide a filtering process, wherein the system state estimates are obtained by using, selectively, forward estimating solution, and combined forward estimating solution and backward smoothing solution.

Accordingly, in order to accomplish the above objectives, the present invention provides a filtering process which comprises the steps of:

(a) computing a model relevant information for a time update and a measurement update in a model selection; and

(b) providing, from the model selection, an initial condition of a system estimate for a system model computation in the time update, an initial condition of a covariance error matrix for a derivative system model computation in the time update, a system model for the system model computation in the time update, a derivative system model for the derivative system model computation in the time update, a measurement model for a measurement model computation in the measurement update, and a derivative measurement model for a derivative measurement model computation in the measurement update.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a filtering process of the present invention.

FIG. 2 is a block diagram of the filtering process of the present invention, illustrating the measurement data validation process thereof.

FIG. 3 is a block diagram illustrating the fuzzy logic inference process of the filtering process of the present invention.

FIG. 4 is a block diagram illustrating the first preferred implementation of the state estimate module, forward filtering, according to the filtering process of the present invention.

FIG. 5 is a functional block diagram illustrating the second preferred implementation of the state estimate module, backward smoothing, according to the filtering process of the present invention.

FIG. 6 is a graphical illustration showing the procedures of determining the time steps in the time update according to the filtering process of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention substantially solves the problems of extracting internal state information of a dynamic system from noisy measurements. The present invention provides a method that automatically determines the time step in the propagation of the system state estimate between two consecutive measurement instants in the time update, based upon accuracy and convergence considerations. The present invention eliminates the requirement of selecting a discretization time to discretize a continuous-time differential model into a discrete-time difference model prior to the design of the filter, which is the primary first step in the conventional approach.

Referring to FIG. 1, the filtering process of the present invention comprises the following steps.

(a) Input measurement data, such as target position in the tracking applications, from a measurement input interface 10 into a fuzzy logic validation module 15.

(b) Provide an expected measurement in the fuzzy logic validation module.

(c) Validate the input measurement data through a fuzzy logic inference process in the fuzzy logic validation module 15, by comparing with the expected measurement, and

(i) outputting an approved measurement to a state estimate module 20 by approving the input measurement data by the fuzzy logic validation module 15 when a discrepancy between the expected measurement and the input measurement data lies close within a prescribed acceptance range, wherein the input measurement is considered to be useful and accepted;

(ii) outputting a rejected-measurement flag to the state estimate module 20 by rejecting the input measurement data by the fuzzy logic validation module 15 when the discrepancy between the expected measurement and the input measurement data goes beyond a prescribed rejection range, wherein the measurement input is considered to be useless and rejected; and

(iii) outputting a corrected measurement to the state estimate module 20 by correcting the input measurement data by the fuzzy logic validation module 15 when the discrepancy between the expected measurement and the input measurement data lies between the prescribed acceptance range and the prescribed rejection range, wherein the measurement input is considered to be useful and corrected measurement data are generated.

(d) Produce an estimate of system state based on the approved measurement and corrected measurement output from the fuzzy logic validation module 15 in the state estimate module 20 which processes three different activities based on three different inputs in the fuzzy logic validation module 15, referring to FIG. 2, including

(i) extracting a first estimate of system state from the approved measurement passed from the fuzzy logic validation module 15;

(ii) extracting a second estimate of system state from the corrected measurement sent from the fuzzy logic validation module 15; and

(iii) predicting a third estimate of system state without measurement data when receiving the rejected measurement flag from the fuzzy logic validation module 15.

(e) output the obtained first, second and third estimates of system state by a state estimate output interface 90.

Referring to FIG. 1, the fuzzy logic validation step (c) of the filtering process of the present invention provides a reference standard to examine the quality of the measurement. The kernel of the fuzzy logic validation is a fuzzy rule base, which is established from system dynamics characteristics and measurement relationships. The measurement data are of any nature, including but not limited to target position, velocity, and acceleration in the tracking applications, spectral intensity in different bands in the hyperspectral applications, and accelerometer and gyro measurements in inertial navigation applications. Within the fuzzy logic validation, an expected measurement is computed and compared to the measurement input. When the discrepancy between the expected measurement and the measurement

input lies in a prescribed acceptance range, the measurement input is considered to be useful and accepted. When the discrepancy between the expected measurement and the measurement input goes beyond a prescribed rejection range, the measurement input is considered to be useless and rejected. When the discrepancy between the expected measurement and the measurement input lies between the acceptance range and the rejection range, the measurement input is considered to be useful and corrected measurement data are generated.

The measurement data is provided by the measurement input interface 10 to the fuzzy logic validation module 15. Referring to FIG. 3, the step (c) further comprises the following steps:

(c1) Receive the original measurement data from the measurement input interface 10 in a fuzzifier module 151. Perform a scale mapping on the original measurement data, which transfers the range of measurement into a corresponding universe of discourse. Perform fuzzification and convert the measurement data into suitable linguistic values which are labeled as fuzzy sets. Interpret the crisp measurement data as fuzzy sets with membership functions belonging to [0,1]. Output these fuzzy sets to a fuzzy interface engine 152.

(c2) Receive the fuzzy sets from the fuzzifier module 151 in a fuzzy interface engine 152, wherein human decision making is simulated to infer fuzzy outputs, using fuzzy implication and the fuzzy logic inference rules, and the fuzzy logic inference rules are supported by a fuzzy rule base 153. Send the obtained fuzzy outputs to a defuzzifier module 154.

(c3) Provide the fuzzy logic inference rules for the fuzzy interface engine 152 in the fuzzy rule base 153 which characterizes goals and domain knowledge of experts by means of a set of linguistic rules, wherein the fuzzy rule base 153 comprises the knowledge of the application domain and the attendant goal. Primarily determine the performance of the fuzzy logic validation 15 by the fuzzy rule base 153.

(c4) Receive the fuzzy outputs from the fuzzy interface engine 152 in the defuzzifier module 154. Selectively, it approves the original measurement data (approved measurement) and passes it down without change to the state estimate module 20, generates a crisp corrected measurement data (corrected measurement) that best represents the possibility distribution of the inferred fuzzy outputs from the fuzzy interface engine 152 and outputs the corrected measurement data (corrected measurement) to the state estimate module 20, and rejects the measurement data and outputs the rejected-measurement flag to the state estimate module 20.

In the step (d), the output from the defuzzifier module 154 in the fuzzy logic validation module 15 is processed to produce the estimate of system state in the state estimate module 20. The state estimate module 20 of the present invention provides two options, forward filtering, referring to FIG. 4, and backward smoothing, referring to FIG. 5. Backward smoothing requires that forward filtering be executed first and forward filtering results are stored. Forward filtering is suitable for real-time applications, while backward smoothing is useful in non-real-time applications with a higher accuracy.

To accommodate randomly spaced measurement intervals, the measurement data is required to be clearly time-stamped, such that the interval span between two consecutive valid measurements is computed to monitor how long the state estimate propagates without a measurement update in a time update 202 in the state estimate module 20.

The first preferred processing of the step (d), forward filtering, as shown in FIG. 4, further comprises the following steps.

(d1) Compute a model relevant information for the time update 202 and a measurement update 201 in a model selection 203. Specifically, the model selection 203 provides an initial condition of the system estimate for a system model computation 2021 in the time update 202, an initial condition of the covariance error matrix for a derivative system model computation 2022 in the time update 202, a system model for the system model computation 2021 in the time update 202, a derivative system model for the derivative system model computation 2022 in the time update 202, a measurement model for a measurement model computation 2011 in the measurement update 201, and a derivative measurement model for a derivative measurement model computation 2012 in the measurement update 201.

(d2) Propagate the state estimate during the interval of the last two consecutive valid measurements in the time update 202. The time update is exclusively based upon the system model. Denote by $\hat{x}(t_{k-1})$ and $P(t_{k-1})$ the state estimate and its associated covariance error matrix at time t_{k-1}, respectively, just after the last measurement $z(k-1)$ at t_{k-1} has been processed by the measurement update 201. The step (d2) also comprises the steps of:

(d2-1)

computing the interval span between the last two consecutive valid measurements $z(k-1)$ and $z(k)$, wherein this interval span, calculated by

$$t_k - t_{k-1}$$

determines how long the time update propagates without a measurement update;

(d2-2) receiving the system model from the model selection 203 and computing a time derivative of the system state at the latest estimate of the system state $\hat{x}(t_{k-1})$ in the system model computation 2021,

$$\dot{\hat{x}}(t_{k-1}) = f(\hat{x}(t_{k-1}))$$

(d2-3) receiving the derivative system model from the model selection 203 and computing a time derivative of a covariance error matrix for the system state at the latest estimate of the system state $\hat{x}(t_{k-1})$ in the derivative system model computation 2022,

$$\dot{P}(t_{k-1}) = F(t_{k-1})P(t_{k-1}) + P(t_{k-1})F^T(t_{k-1}) + Q(t_{k-1})$$

where the Jacobian matrix $F(t_{k-1})$ is calculated at $\hat{x}(t_{k-1})$ by

$$F(t_{k-1}) = \left.\frac{\partial f(x)}{\partial x}\right|_{x=\hat{x}(t_{k-1})}$$

(d2-4) propagating the state estimate by utilizing the time derivative of the system state estimate $\hat{x}(t_{k-1})$ computed in the system model computation 2021 in a prediction update 2023, using a Runge-Kutta integration algorithm with adaptive stepsize control,

$$\hat{x}(t_{k-1}) \rightarrow \hat{x}(t_k)$$

(d2-5) propagating the covariance error matrix of the state estimate by utilizing the time derivative of the covariance error matrix $\dot{P}(t_{k-1})$ computed in the derivative

system model computation 2022 in a prediction covariance update 2024, using a factorized implementation which is detailed later, to ensure the symmetry and positive definiteness of P(t) during the propagation,

$$P(t_{k-1}) \rightarrow P(t_k)$$

(d3) Correct the state estimate by using the latest measurement data z(k) at t_k in the measurement update 201. The measurement update is based upon the measurement model and the measurement data. In the case that a rejected-measurement flag is received corresponding to z(k) from the fuzzy logic validation 15, the measurement update for z(k) is skipped and the time update continues. When z(k) is adopted, the results obtained in the time update are utilized as the initial conditions. Denote by $\hat{x}\_(k)$ and $P\_(k)$ the state estimate and its associated covariance error matrix at time t_k, respectively, obtained from the time update 202 just before the last measurement z(k) at t_k is processed by the measurement update 201,

$$\hat{x}\_(k)=\hat{x}(t_k^-)$$

$$P\_(k)=P(t_k^-)$$

wherein the step (d3) further comprises the steps of:

(d3-1) receiving the measurement model from the model selection 203 and computing a predicted measurement at the latest estimate of the system state $\hat{x}\_(k)$ in the measurement model computation 2011, as follows,

$$\hat{z}(k)=h(\hat{x}\_(k))$$

(d3-2) receiving the derivative measurement model from the model selection 203 and computing a measurement Jacobian matrix at the latest estimate of the system state $\hat{x}\_(k)$ in the derivative measurement model computation 2012,

$$H(k)=\left.\frac{\partial h(x)}{\partial x}\right|_{x=\hat{x}\_(k)}$$

(d3-3) updating the covariance error matrix using the measurement update equations in the estimate covariance update 2013, as follows,

$$P_+(k)=[I-K(k)H(k)]P\_(k)$$

$$K(k)=P\_(k)H'(k)\eta^{-1}(k)$$

$$\eta(k)=H(k)P\_(k)H'(k)+R(k)$$

wherein a factorized implementation is detailed later, to ensure the symmetry and positive definiteness of $P_+(k)$.

(d3-4) updating the estimate of the system state using the measurement update equations in the estimate update 2014,

$$\hat{x}_+(k)=\hat{x}\_(k)+K(k)[z(k)-\hat{z}(k)]$$

The steps (d2) and (d3) constitute a complete forward filtering process for the measurement data z(k). When a new valid measurement data z(k+1) becomes available, a new time update is initiated, based on the initial conditions,

$$\hat{x}(t_k)=\hat{x}_+(k)$$

$$P(t_k)=P_+(k)$$

It should be noted that the universal robust filter is applicable to practically any applications, because the user is allowed to change the system model and measurement model to fit his/her own applications via the model selection 203. The model selection is an integral part of the universal robust filter. The system model is described in nonlinear continuous-time differential equations. The measurable model is formulated in nonlinear discrete-time equations.

In some applications where a real time requirement is not stringent and higher accuracy is desired, backward smoothing, which exploits future measurements to improve the current state estimates, is useful. Backward smoothing is not started until the predetermined range of the measurement data has been received. Smoothing is performed backwards in time. The backward filter operates recursively on the measurement data, beginning at the terminal time and proceeding toward the desired smoothing point.

Referring to FIG. 5, the universal robust filter 21 for backward smoothing includes a model selection 213, a forward measurement update 211, a forward time update 212, a backward measurement update 214, and a backward time update 215. The forward measurement update 211 and the forward time update 212 comprise the forward filtering portion. The forward measurement update 211, the forward time update 212, as well as their contained subblocks, a measurement model computation 2111, a derivative measurement model computation 2112, an estimate covariance update 2113, an estimate update 2114, a system model computation 2121, a derivative system model computation 2122, a prediction update 2123, a prediction covariance update 2124, are exactly the same as their corresponding blocks in FIG. 4. The backward measurement update 214 and the backward time update 215 include the backward filtering portion. Forward filtering results and backward filtering results are combined in a smoothed estimate covariance update 216 and a smoothed estimate update 217 to provide smoothed results.

Referring to FIG. 5, the second preferred processing of the step (d), backward smoothing, further comprises the following additional steps:

(d4) Calculate the interval from which a backward smoothed estimate is extracted. By defining $\tau=T-t$ and $\tau_k=T-t_{N-k}$ with T the terminal time, the system dynamic equation and the measurement equation are reformulated as

$$\frac{d}{d\tau}x(T-\tau)=-f(x(T-\tau))+w(T-\tau)$$

$$z(N-k)=h(x(N-k))+v(N-k)$$

(d5) Perform the first preferred processing steps D2 (D2-1 D2-5) and D3 (D3-1~D3-4) to compute the forward state estimate $\hat{x}(t)$ and its covariance error matrix P(t) in the forward measurement update 211 and the forward time update 212.

(d6) Propagate the backward estimate during the interval of the last two consecutive reversed measurements in the backward time update 215. The backward time update is exclusively based upon the backward system model. Define $\hat{x}_b(\tau_{k-1})$ and $P_b(\tau_{k-1})$ the backward state estimate and its associated covariance error matrix for the backward system model at time τ_{k-1}, respectively, just after the last reversed measurement z(N−k+1) has been processed by the backward measurement update 214. The initial condition, $\hat{x}_b(0)$, is chosen as $\hat{x}(T)$, and the initial condition, $P_b(0)$, is set to be a diagonal matrix

with large diagonal elements, wherein the step (d6) further comprise the steps of:

(d6-1) computing the interval span between the last two consecutive reserved valid measurements z(N−k+1) and z(N−k). This interval span, $\tau_k-\tau_{k-1}=t_{N-k+1}-t_{n-k}$, determines how long the backward time update propagates without a measurement update;

(d6-2) receiving the system model and the derivative system model from the model selection 213, computing a system function and a Jacobian matrix at the forward state estimate $\hat{x}(T-\tau_{k-1})$ obtained in forward filtering, and calculating a time derivative of the backward system state in the system model computation 2151,

$$\dot{\hat{x}}_b(\tau_{k-1})=-f(\hat{x}(T-\tau_{k-1}))-F(T-\tau_{k-1})[\hat{x}_b(\tau_{k-1})-\hat{x}(T-\tau_{k-1})]$$

where the Jacobian matrix $F(T-\tau_{k-1})$ is calculated at $\hat{x}(T-\tau_{k-1})$ by

$$F(T-\tau_{k-1})=\left.\frac{\partial f(x)}{\partial x}\right|_{x=\hat{x}(T-\tau_{k-1})}$$

(d6-3) receiving the derivative system model from the model selection 213 and computing a time derivative of the covariance error matrix for the backward system state at the forward state estimate $\hat{x}(T-\tau_{k-1})$ in the derivative system model computation 2152,

$$\dot{P}_b(\tau_{k-1})=-F(T-\tau_{k-1})P_b(\tau_{k-1})-P_b(\tau_{k-1})F^T)(T-\tau_{k-1})+Q(T-\tau_{k-1})$$

(d6-4) propagating the backward state estimate by utilizing the time derivative of the backward system state $\dot{\hat{X}}_b(\tau_{k-1})$ computed in the system model computation 2151 in a backward prediction update 2154, using a Runge-Kutta integration algorithm with adaptive stepsize control,

$$\hat{x}_b(\tau_{k-1})\rightarrow\hat{x}_b(\tau_k)$$

(d6-5) propagating the covariance error matrix of the backward state estimate by utilizing the time derivative of the covariance error matrix $\dot{P}_b(\tau_{k-1})$ computed in the derivative system model computation 2152 in a backward prediction covariance update 2153, using a factorized implementation which is detailed later, to ensure the symmetry and positive definiteness of $P_b(\tau)$ during the propagation,

$$P_b(\tau_{k-1})\rightarrow P_b(\tau_k)$$

(d7) Correct the backward state estimate by using the reversed measurement data z(N−k) at time τ_k in the backward measurement update 214. The measurement update is based upon the measurement model and the measurement data. The results obtained in the backward time update are utilized as the initial conditions. Denote by $\hat{x}_{b-}(k)$ and $P_{b-}(k)$ the backward state estimate and its associated covariance error matrix at time τ_k, respectively, obtained from the backward time update 215 just before the new reversed measurement z(N−k) at time τ_k is processed by the backward measurement update 214,

$$\hat{x}_{b-}(k)=\hat{x}_b(\tau_k^-)$$

$$P_{b-}(k)=P_b(\tau_k^-)$$

wherein the step (d7) further comprises the steps of:

(d7-1) receiving the measurement model from the model selection 213 and computing a predicted measurement at the forward state estimate $\hat{x}(N-k)$ in the measurement model computation 2141,

$$\hat{z}_b(k)=h(\hat{x}(N-k))$$

(d7-2) receiving the derivative measurement model from the model selection 213 and computing a measurement Jacobian matrix at the forward state estimate $\hat{x}(N-k)$ in the derivative measurement model computation 2142,

$$H(N-k)=\left.\frac{\partial h(x)}{\partial x}\right|_{x=\hat{x}(N-k)}$$

(d7-3) updating the covariance error matrix of the backward system estimate using the backward measurement update equations in the backward estimate covariance update 2143,

$$P_{b+}(k)=[I-K_b(k)H(N-k)]P_{b-}(k)$$

$$K_b(k)=P_{b-}(k)H'(N-k)\eta_b^{-1}(k)$$

$$\eta_b(k)=H(N-k)P_{b-}(k)H'(N-k)+R(N-k)$$

wherein a factorized implementation is detailed later, to ensure the symmetry and positive definiteness of $P_{b+}(k)$,

(d7-4) updating the backward state estimate using the backward measurement update equations in the backward estimate update 2144,

$$\hat{x}_{b+}(k)=\hat{x}_{b-}(k)+K_b(k)[z(N-k)-\hat{z}_b(k)-H(N-k)(\hat{x}_b(k)-\hat{x}(N-k))]$$

The steps (d6) and (d7) constitute a complete backward filtering process for the reversed measurement data z(N−k). For the next reversed measurement data z(N−k−1), a new backward time update is started, based on the initial conditions,

$$\hat{x}_b(\tau_k)=\hat{x}_{b+}(k)$$

$$P_b(\tau_k)=P_{b+}(k)$$

(d8) Compute a covariance error matrix for a smoothed state estimate using the covariance error matrix of the forward system estimate and the covariance error matrix of the backward system estimate in a smoothed estimate covariance update 216,

$$P(t|T)=[P^{-1}(t)+P_b^{-1}(t)]^{-1}$$

(d9) Compute the smoothed state estimate using the forward system estimate and the backward system estimate in a smoothed estimate update 217,

$$\hat{x}(t|T)=P(t|T)[P^{-1}(t)\hat{x}(t)+P_b^{-1}(t)\hat{x}_b(t)]$$

To assure filtering/smoothing accuracy and numerical stability, the propagation of the covariance error matrix is accomplished using a factorized implementation. Instead of computing P(t), the factorized implementation propagates $P^{1/2}(t)$ at each iteration, where $P(t)=P^{1/2}(t)\,P^{T/2}(t)$, $P^{1/2}(t)$ is a lower triangular matrix, and $P^{T/2}(t)$ is the upper triangular transpose of $P^{1/2}(t)$.

In the step (d2-5), updating $P^{T/2}(t_{k-1})$ from time t_{k-1} to $t_{k-1}+\Delta t$ is accomplished using the numerically stable QR decomposition,

$$P^{T/2}(t_{k-1})+\left[P^{T/2}(t_{k-1})F^{T}(t_{k-1})+\frac{1}{2}P^{-1/2}(t_{k-1})Q(t_{k-1})\right]\Delta t = \Gamma_1 P^{T/2}(t_{k-1}+\Delta t)$$

The above QR decomposition is completed in two steps. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_1 an orthogonal matrix which satisfies $\Gamma_1^T\Gamma_1=I$. In this process, the orthogonal matrix Γ_1 is not required to be saved. Only the upper triangular matrix $P^{T/2}(t_{k-1}+\Delta t)$, which is the updated covariance error matrix, is needed to be kept.

Referring to FIG. 6, the time step used in updating $P^{T/2}(t_{k-1})$ from time t_{k-1}, Δt, is inherited from step D2-4, in which a Runge-Kutta integration algorithm with adaptive stepsize control is used. Based on the current state estimate, $\hat{x}(t_{k-1})$, and the time derivative of the system state, $\dot{\hat{x}}(t_{k-1})$, the Runge-Kutta adaptive stepsize control integration algorithm produces the stepsize to propagate the state estimate, Δt, and the updated state estimate, $\hat{x}(t_{k-1}+\Delta t)$. It is thus possible that multiple steps are taken for updating $\hat{x}(t_{k-1})$ from time t_{k-1} to t_k. Updating of $P^{T/2}(t_{k-1})$ from time t_{k-1} t exactly same time steps as those used in updating $\hat{x}(t_{k-1})$ from time t_{k-1} to t_k.

In the step (d3-3), updating the covariance error matrix in the measurement update is accomplished using QR decomposition,

$$\begin{pmatrix} R^{T/2}(k) & 0 \\ P_-^{T/2}(k)H^T(k) & P_-^{T/2}(k) \end{pmatrix} = \Gamma_2 \begin{pmatrix} \eta^{T/2}(k) & \eta^{-1/2}(k)H(k)P_-(k) \\ 0 & P_+^{T/2}(k) \end{pmatrix}$$

The QR decomposition is completed similarly. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_2 an orthogonal matrix which satisfies $\Gamma_2^T\Gamma_2=I$. The orthogonal matrix Γ_2 is not required to be saved either.

In the step (d3-4), updating the state estimate in the measurement update is accomplished by utilizing the results obtained in the QR decomposition, as follows,

$$\hat{x}_+(k) = \hat{x}_-(k) + \underbrace{P_-(k)H^T(k)\eta^{-T/2}(k)}_{\text{available in (1,2)-block}}\eta^{-1/2}(k)[z(k) - \hat{z}(k)]$$

The gain above is composed of two terms available from the QR decomposition. The first term, $P_-(k)H^T(k)\eta^{-T/2}(k)$, is directly derived from the transpose of the (1,2)-block of the right-hand side upper triangular matrix. The second term, $\eta^{-1/2}(k)$, is calculated from the inversion of the (1,1)-block of the right-hand side upper triangular matrix.

In the step (d6-5), updating $P_b^{T/2}(\tau_{k-1})$ from time τ_{k-1} to $\tau_{k-1}+\Delta\tau$ is accomplished using QR decomposition,

$$P_b^{T/2}(\tau_{k-1})+\left[-P_b^{T/2}(\tau_{k-1})F^T(T-\tau_{k-1})+\frac{1}{2}P_b^{-1/2}(\tau_{k-1})Q(T-\tau_{k-1})\right]\Delta\tau = \Gamma_3 P_b^{T/2}(\tau_{k-1}+\Delta\tau)$$

The QR decomposition is completed in a similar way. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_3 an orthogonal matrix which satisfies $\Gamma_3^T\Gamma_3=I$. The orthogonal matrix Γ_3 does not have to be saved.

The time step used in updating $P_b^{T/2}(\tau_{k-1})$ from time τ_{k-1}, $\Delta\tau$, is obtained in a similar way to that in forward filtering. In the step (d6-4), based on the current backward state estimate, $\hat{x}_h(\tau_{k-1})$, and the time derivative of the system state, $\dot{\hat{x}}_h(\tau_{k-1})$, a Runge-Kutta integration algorithm with adaptive stepsize control produces the stepsize to propagate the backward state estimate, $\Delta\tau$, and the updated state estimate, $\hat{x}_h(\tau_{k-1}+\Delta\tau)$. It is possible that multiple steps are taken for updating $\hat{x}_h(\tau_{k-1})$ from time τ_{k-1} to τ_k. Updating of $P_b^{T/2}(\tau_{k-1})$ from time τ_{k-1} to τ_k follows the exactly same time steps as those used in updating $\hat{x}_h(\tau_{k-1})$ from time τ_{k-1} to τ_k.

In the step (d7-3), updating the backward covariance error matrix in the backward measurement update is accomplished using QR decomposition,

$$\begin{pmatrix} R^{T/2}(N-k) & 0 \\ P_{b-}^{T/2}(k)H^T(N-k) & P_{b-}^{T/2}(k) \end{pmatrix} = \Gamma_4 \begin{pmatrix} \eta_b^{T/2}(k) & \eta_b^{-1/2}(k)H(N-k)P_{b-}(k) \\ 0 & P_{b+}^{T/2}(k) \end{pmatrix}$$

The QR decomposition is completed similarly. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_4 an orthogonal matrix which satisfies $\Gamma_4^T\Gamma_4=I$. The orthogonal matrix Γ_4 is not required to be saved either.

In the step (d7-4), updating the backward state estimate in the backward measurement update is accomplished by utilizing the results obtained in the QR decomposition,

$$\hat{x}_{b+}(k)=\hat{x}_{b-}(k)+K_b(k)[z(N-k)-\hat{z}_b(k)-H(N-k)(\hat{x}_{b-}(k)-\hat{x}(N-k))]$$

$$K_b(k)=[1,2]^T[1,1]^{-1}$$

where the gain matrix, $K_b(k)$, is composed of two terms available from the QR decomposition. The first term, $P_{b-}(k)H^T(N-k)\eta_b^{-T/2}(k)$, is directly derived from the transpose of the (1,2)-block of the right-hand side upper triangular matrix. The second term, $\eta_b^{-1/2}(k)$, is calculated from the inversion of the (1,1)-block of the right-hand side upper triangular matrix.

The present invention is highly applicable to hyperspectral image processing to detect the presence of a particular material and classify the comprising materials. Hyperspectral image sets contain large amounts of data that are difficult to exploit. Most materials have unique spectral signatures and if that signature can be observed or detected, then these materials can be identified with certainty. Prior techniques for hyperspectral imagery exploitation use classical pattern recognition methods. These methods include model based or least squares approaches to detect and classify materials present in the data. The present invention can be applied to hyperspectral image processing and pixel unmixing.

The application of the present invention to hyperspectral image processing comprises the following steps.

Select the system state elements to be the square root of abundance of the candidate materials, which guarantees the nonnegativeness of the abundance.

Establish a dynamical system model, by converting a two-dimensional spatial index (x,y) into a one-dimensional index k, and assume that the relationship of the square root of the abundance between two adjacent pixels is modeled as a Gauss-Markov process. The rule to the index conversion is that two consecutive pixel in one-dimension indexing must be physically adjacent.

Establish a measurement model, by assuming that the spectrum of a pixel is modeled as a linear mixture of spectral signatures of materials within the pixel. The constraint that

the sum of abundance of all materials within a pixel equals to 1.0 is translated into an extra measurement equation.

Apply the universal robust filtering process in the present invention to estimate the abundance of the comprising materials for each pixel.

It should be noted that the system model established in the above steps is a discrete-time difference model, which is determined by the inherent discrete nature of the hyperspectral problem. The adaptive stepsize control of the present invention is thus unnecessary for the hyperspectral applications. Also, the system model is linear, based upon the Gauss-Markov process assumption for the relationship of the square root of the abundance between two adjacent pixels. Therefore, the hyperspectral image processing is nicely embodied into the application domain of the present invention as a special case.

What is claimed is:

1. A filtering process, comprising the steps of:

(a) computing a model relevant information for a time update and a measurement update in a model selection; and

(b) providing, from said model selection, an initial condition of a system estimate for a system model computation in said time update, an initial condition of a covariance error matrix for a derivative system model computation in said time update, a system model for said system model computation in said time update, a derivative system model for said derivative system model computation in said time update, a measurement model for a measurement model computation in said measurement update, and a derivative measurement model for a derivative measurement model computation in said measurement update.

2. The filtering process, as recited in claim 1, further comprising the steps of:

(c) propagating said state estimate during an interval of last two consecutive valid measurements in said time update which is based upon a system model; and

(d) correcting said state estimate by using a latest measurement data in said measurement update, said measurement update being based upon said measurement model and said measurement data.

3. The filtering process, as recited in claim 2, wherein said step (c) further comprises the steps of:

(c-1) computing an interval span between said last two consecutive valid measurements in order to determine how long said time update propagates without said measurement update;

(c-2) receiving said system model from a model selection and computing a time derivative of said system state at a latest estimate of said system state in said system model computation;

(c-3) receiving said derivative system model from said model selection and computing a time derivative of a covariance error matrix for said system state at said latest estimate of said system state in said derivative system model computation;

(c-4) propagating said state estimate by utilizing said time derivative of said system state computed in said system model computation in a prediction update, using a Runge-Kutta integration algorithm with adaptive stepsize control; and

(c-5) propagating said covariance error matrix of said state estimate by utilizing said time derivative of said covariance error matrix computed in said derivative system model computation in a prediction covariance update, using a factorized implementation.

4. The filtering process, as recited in claim 2, wherein said step (d) further comprises the steps of:

(d-1) receiving said measurement model from said model selection and computing a predicted measurement at a latest estimate of system state in said measurement model computation,

(d-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said latest estimate of system state in said derivative measurement model computation,

(d-3) updating said covariance error matrix by using measurement update equations in said estimate covariance update, and

(d-4) updating an optimal estimate of system state by using said measurement update equations in said estimate update.

5. The filtering process, as recited in claim 3, wherein said step (d) further comprises the step of:

(d-1) receiving said measurement model from said model selection and computing a predicted measurement at a latest estimate of system state in said measurement model computation,

(d-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said latest estimate of system state in said derivative measurement model computation,

(d-3) updating said covariance error matrix by using measurement update equations in said estimate covariance update, and

(d-4) updating an optimal estimate of system state by using said measurement update equations in said estimate update.

6. The filtering process, as recited in claim 4, after the step (d), further comprising the steps of:

(e) calculating an interval from which a backward smoothed estimate is extracted;

(f) obtaining said forward state estimate and a covariance error matrix thereof in a forward measurement update and a forward time update by performing the step (c) and the step (d);

(g) propagating a backward estimate during said interval of said last two consecutive reversed measurements in a backward time update based upon said backward system model so as to define said backward state estimate and said associated covariance error matrix thereof for said backward system model respectively, just after said last reversed measurement being processed by said backward measurement update;

(h) correcting said backward state estimate by using said reversed measurement data in a backward measurement update based upon said measurement model and said measurement data, wherein results obtained in said backward time update are utilized as initial conditions, wherein a state estimate and an associated covariance error matrix thereof obtained from said backward time update just before a new measurement is processed by said backward measurement update;

(i) computing a covariance error matrix for a smoothed state estimate using said covariance error matrix of said forward system estimate and said covariance error matrix of said backward system estimate in a smoothed estimate covariance update; and

(j) computing said smoothed state estimate using said forward system estimate and said backward system estimate in a smoothed estimate update.

7. The filtering process, as recited in claim 5, after the step (d), further comprising the steps of:

(e) calculating an interval from which a backward smoothed estimate is extracted;

(f) obtaining said forward state estimate and a covariance error matrix thereof in a forward measurement update and a forward time update by performing the step (c) and the step (d);

(g) propagating a backward estimate during said interval of said last two consecutive reversed measurements in a backward time update based upon said backward system model so as to define said backward state estimate and said associated covariance error matrix thereof for said backward system model respectively, just after said last reversed measurement being processed by said backward measurement update;

(h) correcting said backward state estimate by using said reversed measurement data in a backward measurement update based upon said measurement model and said measurement data, wherein results obtained in said backward time update are utilized as initial conditions, wherein a state estimate and an associated covariance error matrix thereof obtained from said backward time update just before a new measurement is processed by said backward measurement update;

(i) computing a covariance error matrix for a smoothed state estimate using said covariance error matrix of said forward system estimate and said covariance error matrix of said backward system estimate in a smoothed estimate covariance update; and

(j) computing said smoothed state estimate using said forward system estimate and said backward system estimate in a smoothed estimate update.

8. The filtering process, as recited in claim 6, wherein said step (g) further comprise said steps of:

(g-1) computing said interval span between said last two consecutive reserved valid measurements so as to determine how long said backward time update propagates without a measurement update;

(g-2) receiving said system model and said derivative system model from a model selection, computing a system function and a Jacobian matrix at said forward state estimate obtained in forward filtering, and calculating a time derivative of said backward system state in a system model computation;

(g-3) receiving said derivative system model from said model selection and computing a time derivative of said covariance error matrix for said backward system state at said forward state estimate in a derivative system model computation;

(g-4) propagating said backward state estimate by utilizing said time derivative of said backward system state computed in said system model computation in a backward prediction update, using a Runge-Kutta integration algorithm with adaptive stepsize control; and

(g-5) propagating said covariance error matrix of said backward state estimate by utilizing said time derivative of said covariance error matrix computed in said derivative system model computation in a backward prediction covariance update, using a factorized implementation.

9. The filtering process, as recited in claim 7, wherein said step (g) further comprise said steps of:

(g-1) computing said interval span between said last two consecutive reserved valid measurements so as to determine how long said backward time update propagates without a measurement update;

(g-2) receiving said system model and said derivative system model from a model selection, computing a system function and a Jacobian matrix at said forward state estimate obtained in forward filtering, and calculating a time derivative of said backward system state in a system model computation;

(g-3) receiving said derivative system model from said model selection and computing a time derivative of said covariance error matrix for said backward system state at said forward state estimate in a derivative system model computation;

(g-4) propagating said backward state estimate by utilizing said time derivative of said backward system state computed in said system model computation in a backward prediction update, using a Runge-Kutta integration algorithm with adaptive stepsize control; and

(g-5) propagating said covariance error matrix of said backward state estimate by utilizing said time derivative of said covariance error matrix computed in said derivative system model computation in a backward prediction covariance update, using a factorized implementation.

10. The filtering process, as recited in claim 6, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

11. The filtering process, as recited in claim 7, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

12. The filtering process, as recited in claim 8, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

13. The filtering process, as recited in claim 9, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

* * * * *

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APPLICATION NUMBER: *09/840,426*
FILING DATE: *April 20, 2001*

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

N. Woodson

N. WOODSON
Certifying Officer

04-04-01

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	USP1468H-MWL
First Inventor	Ming King WONG
Title	Interchangable Piezoelectric Lighter
Express Mail Label No.	EL 745709553 US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [X] Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. [X] Applicant claims small entity status. See 37 CFR 1.27.
3. [X] Specification [Total Pages 13] (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [X] Drawing(s) (35 U.S.C. 113) [Total Sheets 4]
5. Oath or Declaration [Total Pages 1]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) (for continuation/divisional with Box 18 completed)
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
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      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
11. [ ] English Translation Document (if applicable)
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [X] Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. [ ] Request and Certification under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: ....

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: ______/______

Prior application information: Examiner ______ Group Art Unit: ______

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

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Signature	[signature]	Date	04/20/2001

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FEE TRANSMITTAL for FY 2001

Patent fees are subject to annual revision.

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Ming King WONG
Examiner Name	
Group Art Unit	
Attorney Docket No.	USP1468H-MWL

TOTAL AMOUNT OF PAYMENT ($) 355.00

METHOD OF PAYMENT

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number

Deposit Account Name

☐ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

☒ Applicant claims small entity status See 37 CFR 1.27

2. ☒ Payment Enclosed:

☒ Check ☐ Credit card ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	710	201	355	Utility filing fee	$355
106	320	206	160	Design filing fee	
107	490	207	245	Plant filing fee	
108	710	208	355	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 355.00

2. EXTRA CLAIM FEES

		Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=
Independent Claims		- 3** =		X		=
Multiple Dependent						=

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	390	216	195	Extension for reply within second month	
117	890	217	445	Extension for reply within third month	
118	1,390	218	695	Extension for reply within fourth month	
128	1,890	228	945	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,240	241	620	Petition to revive - unintentional	
142	1,240	242	620	Utility issue fee (or reissue)	
143	440	243	220	Design issue fee	
144	600	244	300	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	710	246	355	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	710	249	355	For each additional invention to be examined (37 CFR § 1.129(b))	
179	710	279	355	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0

SUBMITTED BY

Complete (if applicable)

Name (Print/Type)	Raymond Y. Chan	Registration No. (Attorney/Agent)	37,484	Telephone	626-571-9812
Signature	Raymond Chan			Date	04/26/2001

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In the United States Patent and Trademark Office

Commissioner of Patents and Trademarks
Washington, District of Columbia 20231

Mailed: April 20, 2001
Attorney Docket: USP1468H-MWL

Sir:

Please file the following enclosed patent application papers:

Applicant #1, Name: Ming King WONG

Applicant #2, Name: ______________________

Title: Interchangeable Piezoelectric Lighter

☒ Specification, Claims, and Abstract Nr. Of Sheets 13

☒ Declaration: Date Signed: ______________________

☒ Drawing(s): Nr. Of Sheets Enc.: (In Triplicate): Formal: 4 Informal: __________

☒ The applicant claims small entity status. See 37 CFR 1.27

☒ Assignment; please record and return; recordal fee enclosed.

☒ Check for $ 355.00 for:

- ☒ $ 355.00 for filing fee (not more than three independent claims and twenty total claims are presented).
- ☒ $ 40.00 Additional of Assignment is enclosed for recordal.

Very respectfully,

Signature
Raymond Y. C. Chan
Reg. Nr. : 37,484

1050 Oakdale Lane,
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Certificate of Mailing

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Title

Interchangeable Piezoelectric Lighter

Background of the Present Invention

Field of Invention

The present invention relates to piezoelectric lighters, and more particularly to an interchangeable piezoelectric lighter which is adapted for selectively interchanging a type of flame between a visible flame, a torch flame, and a windproof flame.

Description of Related Arts

Piezoelectric lighters have been known and sold throughout the United States. The conventional piezoelectric lighters are generally classified into two categories which is the visible flame type piezoelectric lighter and the torch flame type piezoelectric lighter. The visible flame type piezoelectric lighter, such as a cigarette lighter, allows gas emitted from the nozzle directly burned in the air to produce a regular visible flame. A windproof type piezoelectric lighter, has a re-igniting properties wherein an ignition element is heated up when igniting the lighter in such a manner that once the flame is blown out, the ignition element remains in high temperature and re-ignites the emitted gas to regain the flame. Thus, a torch lighter is adapted for providing a high temperature torch flame wherein the torch flame is more powerful than the visible flame so as to increase the burning purpose of the lighter.

For smokers, especially cigar and pipe smokers, do not ready like to use the torch flame type piezoelectric lighter since the high temperature torch flame will destroy the taste of the tobacco. However, it is a hassle for the smoker to light a cigarette or a cigar outdoors while using the visible flame type piezoelectric lighter. Thus, it is inconvenient for the smokers to carry different types of lighter at once.

Moreover, an improved piezoelectric lighter is adapted for selecting the flame by manipulating an ignition button wherein when a downward force is applied on the

ignition button to depress the ignition button, such lighter provides a torch flame and when the downward force is released, the lighter provides a visible flame. However, a user must manipulate the ignition button and leads to different operational results depending on the user, which may be considered disadvantageous in practical use. Thus, the lighter must require other parts to incorporate therewith for controlling a flow of gas. Generally, a lighter cap is incorporated with the lighter for actuating a valve thereof such that when the lighter cap is opened, the gas is released from the gas chamber through the valve. This adverse result affects the ease of leaking the gas from the gas chamber. So, such improved lighter still has drawbacks in practical use and hence there has been a demand for an interchangeable lighter which is improved in both safety and operability.

Summary of the Present Invention

A main object of the present invention is to provide an interchangeable piezoelectric lighter which is adapted for selectively interchanging a type of flame between a visible flame, torch flame, and a windproof flame.

Another object of the present invention is to provide an interchangeable piezoelectric lighter which produces both visible flame, windproof flame, and torch flame for selectively lighting a cigarette, cigar and pipe conveniently.

Another object of the present invention is to provide an interchangeable piezoelectric lighter wherein the visible flame, the torch flame, and the windproof flame are selectively produced by controlling a flame interchanging means such that no mechanism is required for users to manipulate in order to select the flame such as the ignition button.

Another object of the present invention is to provide an interchangeable piezoelectric lighter wherein the lighter is improved in both safety and operability. A user selects a desired flame by manipulating the flame interchanging means and then ignites the lighter in one single action, which is advantageous in practical use.

Accordingly, in order to accomplish the above objects, the present invention provides an interchangeable piezoelectric lighter, comprising:

a casing receiving a liquefied gas storage and a switcher cavity provided therein;

a gas valve operatively extended from the liquefied gas storage for controlling a flow of gas;

a piezoelectric unit fitted in the casing for generating piezoelectricity;

an ignition button slidably fitted in the casing in a vertically movable manner wherein the ignition button is attached to a top end of the piezoelectric unit and arranged to compress the piezoelectric unit when the ignition button is depressed; and

a flame interchanging means for selectively interchanging a flame of the piezoelectric lighter, comprising a valve switcher movably received in the switcher cavity wherein the valve switcher comprises at least two gas nozzles selectively and coaxially aligning with the gas valve for the flow of gas passing therethrough so as to produce different flames.

Brief Description of the Drawings

Fig. 1 is a perspective view of an interchangeable piezoelectric lighter according to a preferred embodiment of the present invention.

Fig. 2 is an exploded perspective view of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

Fig. 3 is a sectional view of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

Fig. 4 illustrates an alternative mode of a flame interchanging means of the interchangeable piezoelectric lighter according to the above preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiment

Referring to Figs. 1 to 3 of the drawings, an interchangeable piezoelectric lighter according to a preferred embodiment of the present invention is illustrated. The interchangeable piezoelectric lighter, such as a standard piezoelectric lighter, comprises a casing 10 receiving a liquefied gas storage 11 and a switcher cavity 12 provided therein, a gas valve 13 operatively extended from the liquefied gas storage 11 for controlling a flow of gas, a piezoelectric unit 14 fitted in the casing 10 for generating piezoelectricity, and an ignition button 15 slidably fitted in the casing 10 in a vertically movable manner.

The piezoelectric unit 14, which is disposed in the casing 10, comprises a movable operating part 141 extended upwardly and an ignition tip 142 extended to a position towards to the gas valve 13, wherein when the movable operating part 141 is depressed downwardly, the ignition tip 142 generates sparks to ignite the gas emitted from the gas valve 13 at the same time.

The ignition button 15 is attached to a top end of the movable operating part 141 of the piezoelectric unit 13 and operatively connected to the gas valve 13 via a gas lever 16. Accordingly, when the ignition button 15 is pushed downward, the movable operating part 141 of the piezoelectric unit 14 is compressed for generating piezoelectricity through and out the ignition tip 142. At the same time, the gas lever 16 is simultaneously pressed by the ignition button 15 to release gas through the gas valve 13 so as to ignite the releasing gas by the spark from the ignition tip 142.

The interchangeable piezoelectric lighter further comprises a flame interchanging means 20 for selectively interchanging a flame of the piezoelectric lighter, comprising a valve switcher 21 movably received in the switcher cavity 12 in a rotatably movable manner wherein the valve switcher 21 comprises at least two gas nozzles 211 selectively and coaxially aligning with the gas valve 13 for the flow of gas passing therethrough so as to produce different flames.

The valve switcher 21 has a lower portion exposed to an exterior of the casing 10 wherein a plurality of flanges 214 are spacedly protruded on an outer circumferential surface of the lower portion of the valve switcher 21 for being rotated easily and an upper portion rotatably received in a cover 18 which is supported on the casing 10. The cover 18 has a through hole 181 provided thereon and arranged to align with gas valve 13 for

the flame passing through. Thus, a cap 19 is pivotally mounted on the cover 18 for protecting the valve nozzle 211.

The flame interchanging means 20 further comprises a gas adapter 22 fitted in the switcher cavity 12 wherein the valve switcher 21 is supported thereon and a gas emitter 22, made of conductive material, having an inlet end operatively extended from the gas valve 13 and a gas releasing end penetrated through the gas adapter 22 so as to selectively align with one of the gas nozzles 211, 212.

According to the preferred embodiment, the valve switcher 21 having a circular shaped rotatably and sealedly mounted on the gas adapter 22 wherein the valve switcher 21 comprises three gas nozzles 211, which are a visible gas nozzle 211a, a torch nozzle 211b, and a windproof nozzle 211c, axially provided on the valve switcher 21 respectively, so as to selectively align with the gas emitter 23. Each of the three gas nozzles 211 has a nozzle head 213 appearing from a ceiling of the valve switcher 21 and a gas inlet 212 provided on a bottom surface of the valve switcher 21 and adapted for sealedly aligning with the gas releasing end of the gas emitter 23 such that the releasing gas is adapted for transmitting from the gas valve 13 to the respective gas nozzle 211 through the gas emitter 23, as shown in Fig. 3.

Accordingly, a gas conduit 17, which is made of non-conductive material such as plastic, is connected between the gas valve 13 and the gas emitter 23 wherein the ignition tip 142 is extended to a position close to the gas emitter 23 in such a manner that the piezoelectricity generated by the piezoelectric unit 14 is transmitted to the gas emitter 23 by conduction for igniting the releasing gas from the gas valve 13. However, the piezoelectricity cannot transmit to the gas valve 13 through the gas conduit 17 because the gas conduit 17 functions as a resistance for resisting the piezoelectricity transmitting therethrough.

The flame interchanging means 20 further comprises a guiding unit 24 for guiding the gas emitter 23 aligned with the respective gas nozzle 211 wherein the guiding unit 24 comprises at least a protrusion 241 upwardly provided on a top surface of the gas adapter 22 and at least a corresponding indention 242 formed on a bottom surface of the valve switcher 21 in such a manner that the protrusion 241 is fittedly engaged with the indention 242 when the gas emitter 23 is aligned with the respective gas nozzle 211, so as to ensure the alignment thereof.

The interchangeable piezoelectric lighter further comprises a supporting frame 30 comprising a central shaft 31 upwardly extended from the switcher cavity 12 wherein the valve switcher 21 is rotatably supported by the central shaft 31 and a resilient element 32 coaxially mounted on the central shaft 31 for applying an urging force against the gas adapter 22.

Accordingly, the valve switcher 21 has a center slot 210 coaxially formed on a bottom surface thereof and the gas adapter 22 has a center through hole 220 coaxially formed thereon in such a manner that the central shaft 31 is penetrated through the center through hole 220 of the gas adapter 22 and rotatably inserted into the center slot 210 of the valve switcher 21.

The resilient element 32, which is a compression spring, is adapted for applying an urging force against the gas adapter 22 to push it upwardly wherein the resilient element 32 has two ends biasing against a base of the central shaft 31 and a bottom surface of the gas adapter 22. Accordingly, the resilient element 32 normally urges and retains the gas adapter 22 in a higher position that the top surface of the gas adapter 22 is tightly contacted with a bottom surface of the valve switcher 21, so as to ensure the gas emitter 23 sealedly aligned with the respective gas nozzle 211 for gas transmitting therebetween.

In order to operate the interchangeable piezoelectric lighter, a user is able to select a type of flame by rotating the valve switcher 21 until the respective gas nozzle 211 is aligned with the gas emitter 23. Then, a downward force must be applied on the ignition button 15 to compress the piezoelectric unit 14 to ignite the piezoelectric lighter of the present invention, as the same as the ignition of the conventional lighter. So, the user does not have to manipulate any part of the lighter to select the flame during the ignition process, which is advantageous in practical use. Thus, for safety purpose, the gas is released from the gas valve 13 which is actuated by the ignition button 15 such that when the downward force is released on the ignition button 15, the gas valve 13 is shut off for preventing the gas releasing accidentally.

Fig. 4 illustrates an alternative mode of the flame interchanging means 20' wherein the valve switcher 21' movably received in the switcher cavity 12' in a horizontally movable manner and arranged to be movably supported on the gas adapter 22'. The valve switcher 21' comprises two gas nozzles 211' which are a visible nozzle

211a' and a torch flame 211b' parallelly provided on the valve switcher 21' respectively, so as to selectively align with the gas emitter 23'. Each of the two gas nozzles 211' has a nozzle head 213' appearing from a ceiling of the valve switcher 21' and a gas inlet 212' provided on a bottom surface of the valve switcher 21' and adapted for sealedly aligning with the gas releasing end of the gas emitter 23' such that the releasing gas is adapted for transmitting from the gas valve 13' to the respective gas nozzle 211' through the gas emitter.

Accordingly, the valve switcher 21' has an elongated guiding slot 210' transversely formed on the bottom surface thereof wherein a head portion of the central shaft 31' of the supporting frame 30' is fitted into the elongated slot 210' in such a manner that the valve switcher 21' is adapted for slidably moving on the gas adapted 22' in a horizontally movable manner. Thus, the guiding slot 210' has a predetermined length adapted for each of the gas nozzles 211' coaxially aligning with the gas emitter 23' and for reinforcing the displacement of the valve switcher 21' so as to prevent the valve switcher 21' departing from the gas adapter 22' when the valve switcher 21' is being pushed.

So, the user is able to select the type of flame by pushing the valve switcher 21' horizontally so as to line up the one of the gas nozzles 211' to the gas emitter 23'. Then the user can simply ignite the piezoelectric lighter of the present invention by pressing the ignition button 15' downwardly as the conventional lighter.

What is Claimed is:

1. An interchangeable piezoelectric lighter, comprising:

a casing receiving a liquefied gas storage and having a switcher cavity provided therein;

a gas valve operatively extended from said liquefied gas storage for controlling a flow of gas;

a piezoelectric unit fitted in said casing for generating piezoelectricity;

an ignition button mounted to said casing in a movable manner, wherein said ignition button is arranged to compress said piezoelectric unit when said ignition button is depressed; and

a flame interchanging means for selectively interchanging a flame of said piezoelectric lighter, comprising a valve switcher movably received in said switcher cavity, wherein said valve switcher comprises at least two gas nozzles selectively and coaxially aligning with said gas valve for said flow of gas passing therethrough so as to produce different flames.

2. An interchangeable piezoelectric lighter. as recited in claim 1, wherein said flame interchangeable means further comprises a gas adapter fitted in said switcher cavity wherein said valve switcher is supported on said gas adapter and a gas emitter having an inlet end operatively extended from said gas valve and a gas releasing end penetrated through said gas adapter so as to selectively align with one of said gas nozzles.

3. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said valve switcher, which is adapted for coaxially rotating with respect to said gas adapter, comprises three gas nozzles which are a which are a visible gas nozzle, a torch nozzle, and a windproof nozzle axially provided on said valve switcher respectively, so as to selectively align with said gas emitter, each of said three gas nozzles having a nozzle head appearing from a ceiling of said valve switcher and a gas inlet provided on a

bottom surface of said valve switcher and adapted for sealedly aligning with said gas releasing end of said gas emitter.

4. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

5. An interchangeable piezoelectric lighter, as recited in claim 3, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

6. An interchangeable piezoelectric lighter, as recited in claim 2, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

7. An interchangeable piezoelectric lighter, as recited in claim 3, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

8. An interchangeable piezoelectric lighter, as recited in claim 5, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has a center slot coaxially formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and rotatably inserted into said center slot of said valve switcher.

9. An interchangeable piezoelectric lighter, as recited in claim 6, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

10. An interchangeable piezoelectric lighter, as recited in claim 7, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

11. An interchangeable piezoelectric lighter, as recited in claim 8, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

12. An interchangeable piezoelectric lighter, as recited in claim 2, wherein said valve switcher, which is movably supported on said gas adapter in a horizontally movable manner, comprises two gas nozzles which are a visible nozzle and a torch flame

parallelly provided on said switcher respectively, so as to selectively align with said gas emitter, each of said two gas nozzles having a nozzle head appearing from a ceiling of said valve switcher and a gas inlet provided on a bottom surface of said valve switcher and adapted for sealedly aligning with said gas releasing end of said gas emitter.

13. An interchangeable piezoelectric lighter, as recited in claim 12, wherein said flame interchanging means further comprises a guiding unit for guiding said gas emitter aligned with said respective gas nozzle wherein said guiding unit comprises at least a protrusion upwardly provided on a top surface of said gas adapter and at least a corresponding indention formed on said bottom surface of said valve switcher in such a manner that said protrusion is fittedly engaged with said indention when said gas emitter is aligned with one of said gas nozzles.

14. An interchangeable piezoelectric lighter, as recited in claim 12, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has an elongated guiding slot transversely formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and slidably inserted into said guiding slot of said valve switcher.

15. An interchangeable piezoelectric lighter, as recited in claim 13, further comprising a supporting frame comprising a central shaft, upwardly extended from said switcher cavity, for rotatably supporting said central shaft and a resilient element coaxially mounted on said central shaft for applying an urging force against said gas adapter, wherein said valve switcher has an elongated guiding slot transversely formed on said bottom surface thereof and said gas adapter has a center through hole coaxially formed thereon in such a manner that said central shaft is penetrated through said center through hole of said gas adapter and slidably inserted into said guiding slot of said valve switcher.

16. An interchangeable piezoelectric lighter, as recited in claim 14, wherein said has a predetermined length adapted for each of said gas nozzles coaxially aligning with said gas emitter and for reinforcing a displacement of said valve switcher.

17. An interchangeable piezoelectric lighter, as recited in claim 15, wherein said has a predetermined length adapted for each of said gas nozzles coaxially aligning with said gas emitter and for reinforcing a displacement of said valve switcher.

18. An interchangeable piezoelectric lighter, as recited in claim 14, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

19. An interchangeable piezoelectric lighter, as recited in claim 15, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

20. An interchangeable piezoelectric lighter, as recited in claim 17, wherein said resilient element is a compression spring having two ends biasing against a base of said central shaft and a bottom surface of said gas adapter, and wherein said resilient element normally urges and retains said gas adapter in a higher position that said top surface of said gas adapter is tightly contacted with said bottom surface of said valve switcher, so as to ensure said gas emitter sealedly aligned with said respective gas nozzle for gas transmitting therebetween.

Interchangeable Piezoelectric Lighter

Abstract of the Disclosure

An interchangeable piezoelectric lighter includes a casing having a switcher cavity and a valve switcher rotatably received in the switcher cavity wherein the valve switcher includes at least two gas nozzles axially provided therein. The gas nozzles are adapted for selectively and coaxially aligning with a gas valve for producing different types flames. Therefore, by rotatably switching the valve switcher, the gas valve is adapted to align with the respective gas nozzle for a releasing gas passing therethrough, so as to produce a desired type of flame.

Attorney/Docket No: USP1468A=MWL

DECLARATION FOR UTILITY PATENT APPLICATION

As a below named inventor, I hereby declare that:
My residence, mailing address, and citizenship are as stated below next to my name.
I believe I am the original, first and sole inventor (if only one name is lited below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Interchangable Piezoelectric Lighter ,

the specification of which is attached hereto unless the following box is checked:

☐ was filed on ______ as United States Application Number or PCT International Application Number ______ and was amended on ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.
I acknowledge the duty to disclose information which is materid to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing data of the prior application and the national or PCT international filing date of the continuatim-in-part application.
I hereby claim foreign priority benefits under 35 USC 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country otherthan the United States of America, listed below and have also identified below, by checking bos, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

			Priority Claimed	Certified Copy Attached
(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No	☐ Yes ☐ No
(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No	☐ Yes ☐ No
(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No	☐ Yes ☐ No

☐ Additional foreign application numbers are listed on a supplemental priority data sheet attached hereto.

I hereby claimed the benefit under 35 USC 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (Day/Month/Year)

☐ Additional provisional application numbers are listed on a supplemental priority data sheet attached hereto.

I hereby appoint the following attorney(s) and/or agent(s), with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Raymond Yat Chan, Reg. No. 37,484
Address all correspondence to: **1050 Oakdale Lane, Arcadia, CA 91006-2222, U.S.A.**
Telephone Calls to: **(626) 571-9812**
Facsimile Calls to: **(626) 571-9813**

I hereby declare that all Statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor (given name, family name) Ming King Wong

Inventor's signature ______ Date 04/18/2001
Residence Same as below Citizenship Hong Kong, P.R.C.
Mailing Address 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong

Full name of second joint inventor, if any (given name, family name) ______

Second Inventor's signature ______ Date ______
Residence ______ Citizenship ______
Mailing Address ______

☐ Additional inventors are being named on separately numbered sheets attached hereto.

Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

09840459 . 042401

Applicant or Patentee: ______ Attorney's Docket No.: USP1468A-MWL
Serial or Patent No.: ______
Filed or Issued: ______
For: ______

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9 (f) and 1.27 (c)) – SMALL BUSINESS CONCERN

I hereby declare that I am

- ☐ the owner of the small business concern identified below:
- ☒ an official of the small business concern empowered to act on behalf of the concern identified below:

Name of Concern: Ming Wide Lighter Co., Ltd.
Address of Concern: 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9 (d), for purposes of paying reduced fees under section 41(a) and (b) of title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power of control the other, or a third party or parties controls or has the power to control both.
I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention entitled:
Interchangable Piezoelectric Lighter
described in:

- ☒ the specification filed herewith
- ☐ application serial no. ______, filed ______
- ☐ patent no. ______, issued ______

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below * and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(d) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).
*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as a small entities. (37 CFR 1.27)

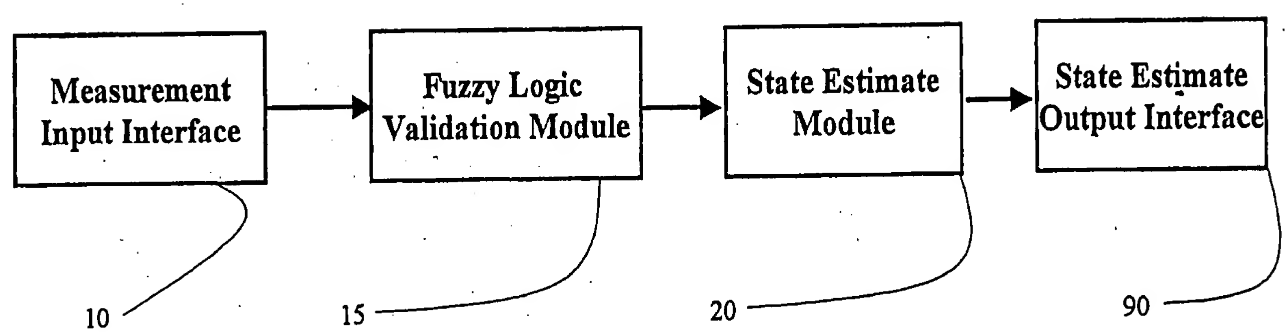
Full Name:
Address: ☐ INDIVIDUAL ☑ SMALL BUSINESS CONCERN ☐ NON PROFIT ORGANIZATION

Full Name:
Address: ☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NON PROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28 (b))
I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statements is directed.

Name of Person Signing: Ming King Wong
Title of Person Other than Owner: Officer
Address of Person Signing: 12/F, North Point Ind., Bldg., 499 King's Road, North Point, Hong Kong

Signature ______ 04/18/2001
Date



Measurement Input Interface
Fuzzy Logic Validation Module
State Estimate Module
State Estimate Output Interface
10
15
20
90

FIG. 1

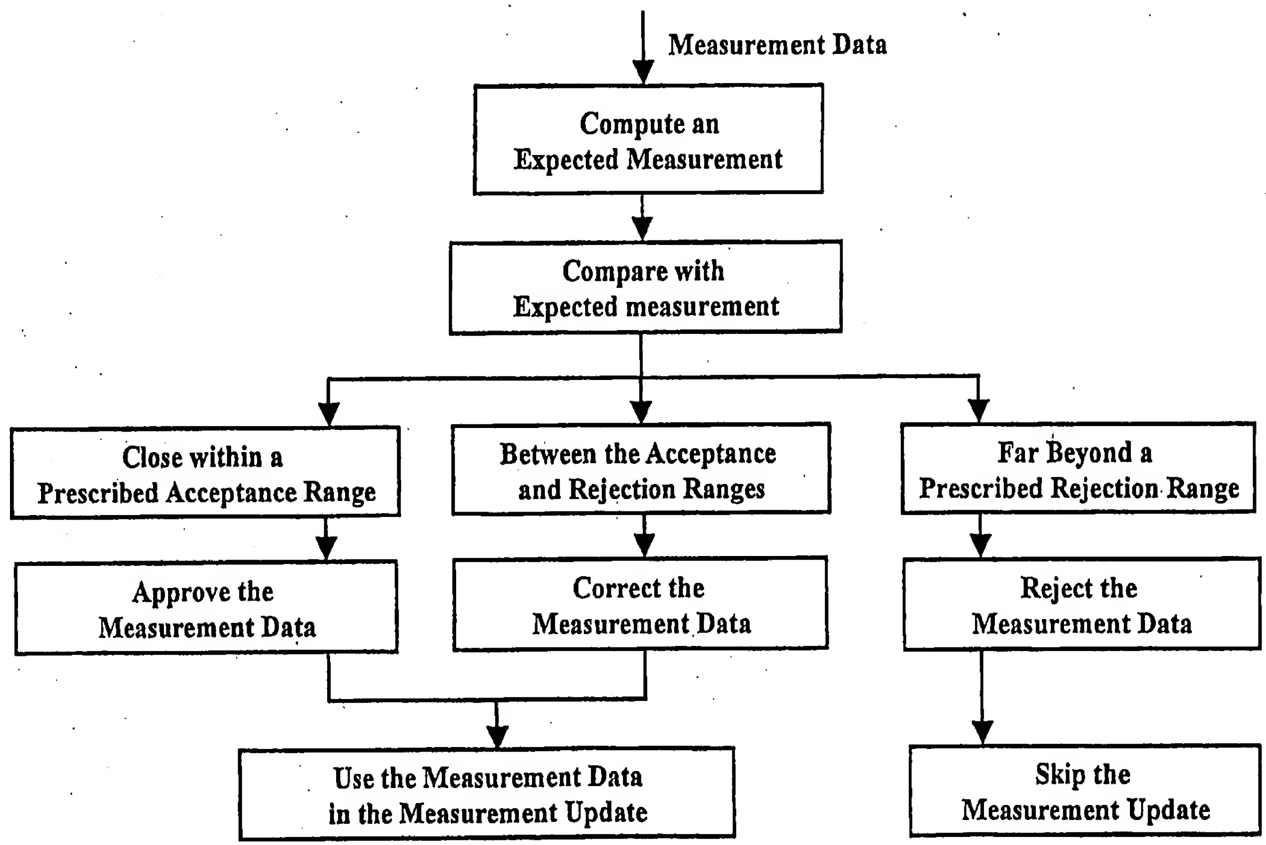
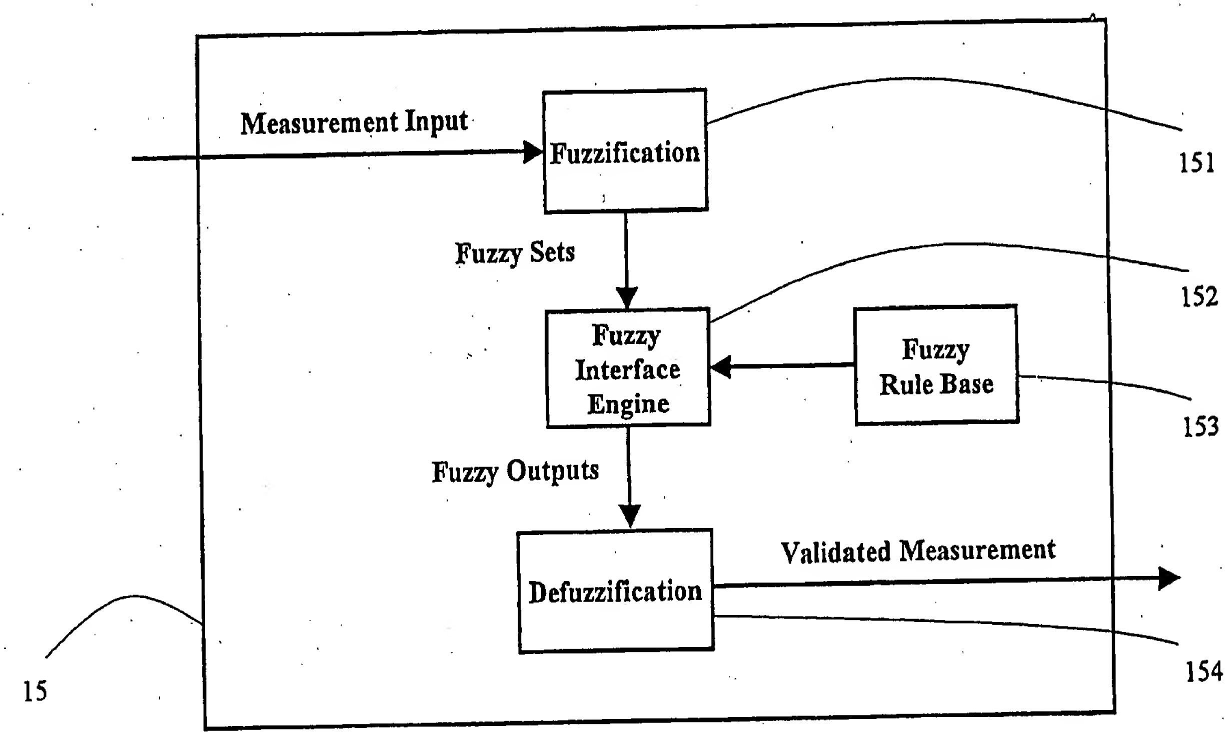

Measurement Data
Compute an Expected Measurement
Compare with Expected measurement
Close within a Prescribed Acceptance Range
Between the Acceptance and Rejection Ranges
Far Beyond a Prescribed Rejection Range
Approve the Measurement Data
Correct the Measurement Data
Reject the Measurement Data
Use the Measurement Data in the Measurement Update
Skip the Measurement Update

FIG. 2


Measurement Input
Fuzzification
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Fuzzy Sets
152
Fuzzy
Interface
Engine
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Rule Base
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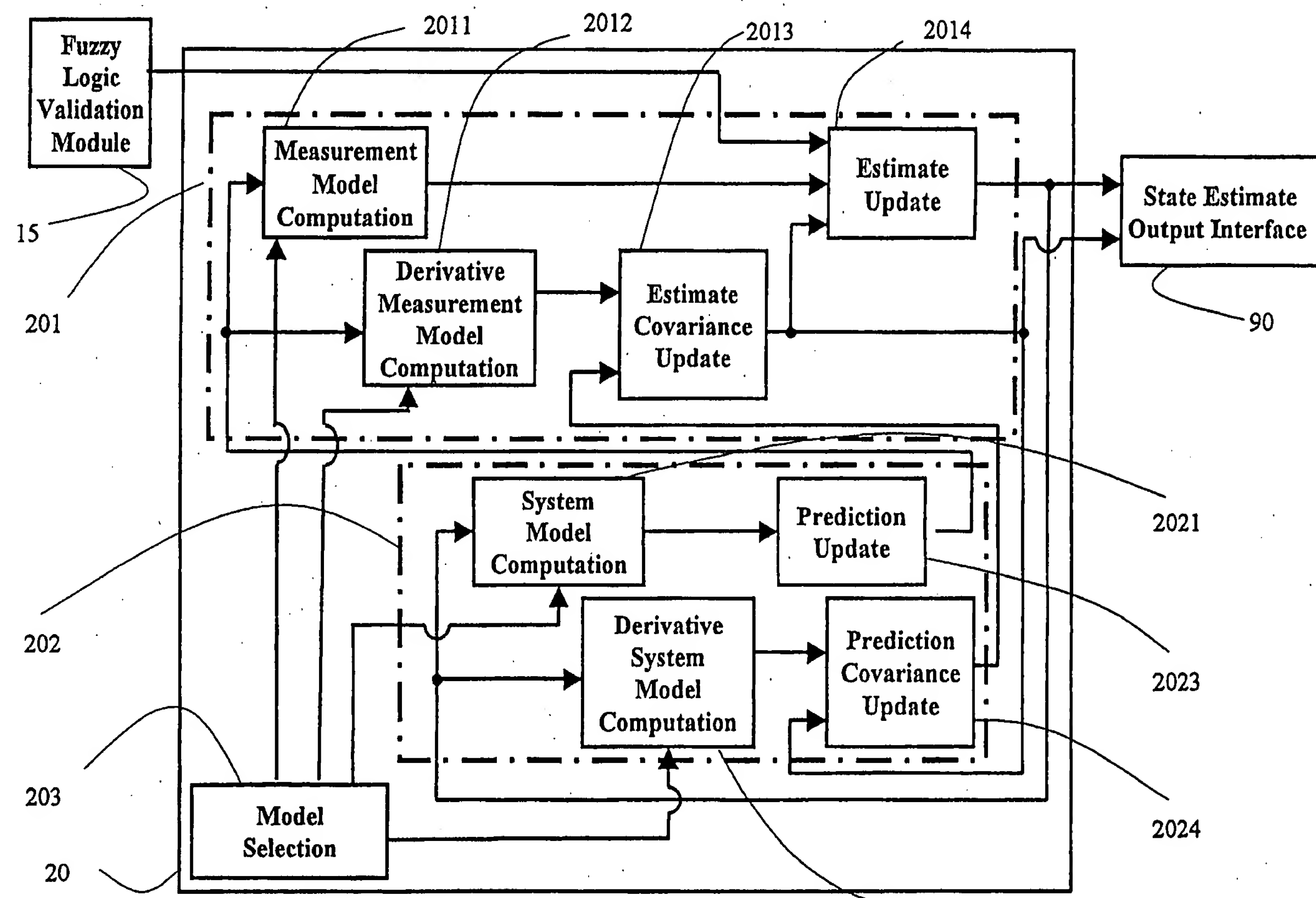
Fuzzy Outputs
Defuzzification
Validated Measurement
15
154

FIG. 3


Fuzzy Logic Validation Module
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2011
2012
2013
2014
Measurement Model Computation
Derivative Measurement Model Computation
Estimate Covariance Update
Estimate Update
State Estimate Output Interface
90
202
System Model Computation
Prediction Update
Derivative System Model Computation
Prediction Covariance Update
2021
2023
2024
2022
203
Model Selection
20

FIG. 4

PA 777399

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

August 15, 2005

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: *09/840,511*
FILING DATE: *April 20, 2001*

By Authority of the
Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office

T. Wallace
T. WALLACE
Certifying Officer

4-24-01

A

J1025 U.S. PTO

PTO/SB/05 (11-00)
Approved for use through 10/31/2002. OMB 0651-0032
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JC040 U.S. PTO 09/840511 04/20/01

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	USP1503A-GNC
First Inventor	Ching-FAng LIN
Title	Filtering Process for Stable and Accurate Estimation
Express Mail Label No.	EL745709567US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [X] Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. [X] Applicant claims small entity status. See 37 CFR 1.27.
3. [X] Specification [Total Pages 32] (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [X] Drawing(s) (35 U.S.C. 113) [Total Sheets 6]
5. Oath or Declaration [Total Pages]
   - a. [ ] Newly executed (original or copy)
   - b. [ ] Copy from a prior application (37 CFR 1.63 (d)) (for continuation/divisional with Box 18 completed)
     - i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   - a. [ ] Computer Readable Form (CRF)
   - b. Specification Sequence Listing on:
     - i. [ ] CD-ROM or CD-R (2 copies); or
     - ii. [ ] paper
   - c. [ ] Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
11. [ ] English Translation Document (if applicable)
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [X] Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. [ ] Request and Certification under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: ....

ASSIGNMENT 4- COVER SHEET.

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

[ ] Continuation [X] Divisional [ ] Continuation-in-part (CIP) of prior application No.: 09 ,551,897

Prior application information: Examiner ______ Group Art Unit: 2721

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[ ] Customer Number or Bar Code Label (Insert Customer No. or Attach bar code label here) or [X] Correspondence address below

Name	David and Raymond Patent Group				
Address	1050 Oakdale Lane				
City	Arcadia	State	CA	Zip Code	91006
Country	USA	Telephone	626-5719812	Fax	626-5719813

Name (Print/Type)	Raymond Y. Chan	Registration No. (Attorney/Agent)	37,484
Signature	[signature]	Date	04/20/2001

09840511.042001

PTO/SB/17 (11-00)
Approved for use through 10/31/2002. OMB 0651-0032
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FEE TRANSMITTAL for FY 2001

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT ($) 355.00

Complete if Known	
Application Number	09/551,897
Filing Date	04/19/2000
First Named Inventor	Ching-Fang Lin
Examiner Name	
Group Art Unit	2721
Attorney Docket No.	USP1503A-GNC

METHOD OF PAYMENT

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number:

Deposit Account Name:

☐ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

☒ Applicant claims small entity status. See 37 CFR 1.27

2. ☒ **Payment Enclosed:**

☒ Check ☐ Credit card ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	710	201	355	Utility filing fee	355
106	320	206	160	Design filing fee	
107	490	207	245	Plant filing fee	
108	710	208	355	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 355

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0

***or number previously paid, if greater; For Reissues, see above*

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for ex parte reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	390	216	195	Extension for reply within second month	
117	890	217	445	Extension for reply within third month	
118	1,390	218	695	Extension for reply within fourth month	
128	1,890	228	945	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,240	241	620	Petition to revive - unintentional	
142	1,240	242	620	Utility issue fee (or reissue)	
143	440	243	220	Design issue fee	
144	600	244	300	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	710	246	355	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	710	249	355	For each additional invention to be examined (37 CFR § 1.129(b))	
179	710	279	355	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 0

SUBMITTED BY				Complete *(if applicable)*	
Name (Print/Type)	Raymond Y. Chan	Registration No. *(Attorney/Agent)*	37,484	Telephone	626-571-9812
Signature	[signature]			Date	08/28/2001

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In the United States Patent and Trademark Office

Commissioner of Patents and Trademarks
Washington, District of Columbia 20231

Mailed: April 20, 2001
Attorney Docket: USP1503A-GNC

Sir:

Please file the following enclosed patent application papers:

Applicant #1, Name: Ching-Fang LIN

Applicant #2, Name: ______________________

Title: Filtering Process for Stable and Accurate Estimation (Divisional application of non-provisional no.: 09/551,897; filed 04/19/2000.)

☒ Specification, Claims, and Abstract: Nr. Of Sheets 32

☐ Declaration: Date Signed: ______________

☒ Drawing(s): Nr. Of Sheets Enc.: (In Triplicate): Formal: 6 Informal: ________

☒ The applicant claims small entity status. See 37 CFR 1.27

☐ Assignment; please record and return; recordal fee enclosed.

☒ Check for $ 355.00 for:

☒ $ 355.00 for filing fee (not more than three independent claims and twenty total claims are presented).

☐ $ __________ Additional of Assignment is enclosed for recordal.

Very respectfully,

Signature
Raymond Y. C. Chan
Reg. Nr. : 37,484

1050 Oakdale Lane,
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I hereby certify that this paper or fee is being deposited with the United States Postal Service using "Express Mail Post Office To Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to "Commissioner of Patents and Trademarks, Washington, DC 20231".

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Title

Filtering Process for Stable and Accurate Estimation

Cross Reference of Related Application

This is a divisional application of a non-provisional application, application number of 09/551,897, filed April 19, 2000.

Field of the Present Invention

The present invention relates to robust information extraction, and more particularly to a filtering process for stable and accurate estimation.

Background of the Present Invention

In most information extraction applications, propagation of an internal state of a dynamic system, which is not measurable by sensors directly, is naturally described by nonlinear continuous-time differential equations, based upon physical laws,

$$\dot{\mathbf{x}}(t) = \mathbf{f}(\mathbf{x}(t)) + \mathbf{w}(t)$$

where $\mathbf{x}(t)$ is a state vector, $\mathbf{f}(\mathbf{x})$ is a vector nonlinear function describing the system dynamics, and $\mathbf{w}(t)$ is a system noise with a covariance matrix $\mathbf{Q}(t)$.

Measurable quantities, which are generally available at intermittent discrete times, are usually in nonlinear relationship with the internal system states,

$$\mathbf{z}(k) = \mathbf{h}(\mathbf{x}(k)) + \mathbf{v}(k)$$

where $\mathbf{z}(k)$ represents a discrete measurement at the k-th sampling time t_k, $\mathbf{h}(\mathbf{x})$ is a vector nonlinear function which describes the relationship of the measurement with the state vector, and $\mathbf{v}(k)$ is a measurement noise with a covariance of $\mathbf{R}(k)$.

A filtering process deals with the problem of extracting the internal, sometimes hidden and unmeasurable, state, $\mathbf{x}(t)$, from the measurement $\mathbf{z}(k)$. Applications of the filtering process are very common, to name a few, such as classifying the component materials from hyperspectral imagery, obtaining the aircraft position and attitude from the accelerometer and gyro measurements of an Inertial Measurement Unit, and tracking a target's velocity and acceleration from a Radar's positional measurements.

Under the conditions of a linear system with linear measurements, a Gaussian system noise and a Gaussian measurement noise, a linear Kalman filter provides an optimal estimate of the internal system state. The estimate is optimal in the sense that the covariance of the estimate is minimal, the residuals are a white Gaussian noise process, and innovative information is absent in the residuals. If selectively, the system model and the measurement model are nonlinear, extracting an estimate of the internal system state, $\mathbf{x}(t)$, from noisy measurements, $\mathbf{z}(k)$, is conventionally accomplished by an extended Kalman filter, and selectively, in some cases, by a variant of the extended Kalman filter. An extended Kalman filter shares most of the salient features with a linear Kalman filter, by linearizing the nonlinear system equations and measurement equations about the most recent estimate and taking a first-order approximation to a Taylor-series expansion.

In the nonlinear cases, an optimal estimate of the system state is difficult for the extended Kalman filter to attain. A direct implementation of an extended Kalman filter possesses several inherent drawbacks. First, it is prone to numerical divergence. The correct propagation of the state estimates relies on the proper propagation of a covariance error matrix, which must remain symmetric and positive definite all the time, due to its mathematical definition. Finite-length manipulations, such as computer roundoff error,

usually result in a loss of the symmetry and positive definiteness of the covariance error matrix resulting in numerical instability. A feasible approach is unavailable to recover from such a numerical divergence status.

An extended Kalman filter passively accepts measurements and is sensitive to measurement quality. Conventionally, it accepts whatever measurement data the measurement input interface provides in full confidence. The Kalman filter is unable to distinguish good-quality measurements from low-quality ones. It generally does not attempt to correct the measurement data by any means even though there might be enough evidence that the quality of measurement data is very poor. When the quality of the measurements applied to the Kalman filter is worse than that accounted for by the measurement noise, the results generated by the Kalman filter are usually meaningless, and yet, it is difficult to determine whether the results are meaningless.

Another difficulty in a conventional extended Kalman filter is the requirement of discretizing the continuous-time differential model into a discrete-time difference model. This in turn requires the selection of a discretization time prior to the design of the extended Kalman filter. A standard method is to set the discretization time the same as the sampling period of the measurements. Such a prediscretization approach does not guarantee that the discrete-time difference model is a good approximation to the continuous-time differential model, especially in the case of a slow sampling rate. Neither is this prediscretization approach able to detect a divergence of the discrete-time difference model from the continuous-time differential model when the divergence occurs.

Summary of the Present Invention

An objective of the present invention is to provide a filtering process for the most general formulation, in the sense that the system dynamics are described by nonlinear continuous-time differential equations, and the nonlinear measurements are taken at intermittent discrete times randomly spaced, wherein the selection of a discretization time for the continuous-time differential model is unnecessary, which possesses wider applications, better accuracy, better stability, easier design, and easier implementation.

Another objective of the present invention is to provide a filtering process, wherein the propagation of the system state estimate between two consecutive measurement instants in the time update is governed by an adaptive stepsize control, which automatically determines the time step and guarantees the convergence.

Another objective of the present invention is to provide a filtering process, which validates measurement data, in order to reject poor-quality measurement data before they are fed into the filter.

Another objective of the present invention is to provide a filtering process, which corrects measurement data, in order to correct low-quality measurement data before they are fed into the filter.

Another objective of the present invention is to provide a filtering process, comprising an adaptive stepsize control to automatically compute the stepsize to propagate the backward state estimate in the backward time update.

Another objective of the present invention is to provide a filtering process, wherein square root implementations are enforced for covariance matrix propagation, wherever applied, to ensure numerical stability.

Another objective of the present invention is to provide a filtering process, wherein the system state estimates are obtained by using, selectively, forward estimating solution, and combined forward estimating solution and backward smoothing solution.

Accordingly, in order to accomplish the above objectives, the present invention provides a filtering process which comprises the steps of:

(a) computing a model relevant information for a time update and a measurement update in a model selection; and

(b) providing, from the model selection, an initial condition of a system estimate for a system model computation in the time update, an initial condition of a covariance error matrix for a derivative system model computation in the time update, a system model for the system model computation in the time update, a derivative system model for the derivative system model computation in the time update, a measurement model for a measurement model computation in the measurement update, and a derivative measurement model for a derivative measurement model computation in the measurement update.

Brief Description of the Drawings

Figure 1 illustrates a filtering process of the present invention.

Figure 2 is a block diagram of the filtering process of the present invention, illustrating the measurement data validation process thereof.

Figure 3 is a block diagram illustrating the fuzzy logic inference process of the filtering process of the present invention.

Figure 4 is a block diagram illustrating the first preferred implementation of the state estimate module, forward filtering, according to the filtering process of the present invention.

Figure 5 is a functional block diagram illustrating the second preferred implementation of the state estimate module, backward smoothing, according to the filtering process of the present invention.

Figure 6 is a graphical illustration showing the procedures of determining the time steps in the time update according to the filtering process of the present invention.

Detailed Description of the Preferred Embodiment

The present invention substantially solves the problems of extracting internal state information of a dynamic system from noisy measurements. The present invention provides a method that automatically determines the time step in the propagation of the system state estimate between two consecutive measurement instants in the time update, based upon accuracy and convergence considerations. The present invention eliminates the requirement of selecting a discretization time to discretize a continuous-time differential model into a discrete-time difference model prior to the design of the filter, which is the primary first step in the conventional approach.

Referring to Figure 1, the filtering process of the present invention comprises the following steps.

(a) Input measurement data, such as target position in the tracking applications, from a measurement input interface 10 into a fuzzy logic validation module 15.

(b) Provide an expected measurement in the fuzzy logic validation module.

(c) Validate the input measurement data through a fuzzy logic inference process in the fuzzy logic validation module 15, by comparing with the expected measurement, and

(i) outputting an approved measurement to a state estimate module 20 by approving the input measurement data by the fuzzy logic validation module 15 when a discrepancy between the expected measurement and the input measurement data lies close within a prescribed acceptance range, wherein the input measurement is considered to be useful and accepted;

(ii) outputting a rejected-measurement flag to the state estimate module 20 by rejecting the input measurement data by the fuzzy logic validation module 15 when the discrepancy between the expected measurement and the input measurement data goes

beyond a prescribed rejection range, wherein the measurement input is considered to be useless and rejected; and

(iii) outputting a corrected measurement to the state estimate module 20 by correcting the input measurement data by the fuzzy logic validation module 15 when the discrepancy between the expected measurement and the input measurement data lies between the prescribed acceptance range and the prescribed rejection range, wherein the measurement input is considered to be useful and corrected measurement data are generated.

(d) Produce an estimate of system state based on the approved measurement and corrected measurement output from the fuzzy logic validation module 15 in the state estimate module 20 which processes three different activities based on three different inputs in the fuzzy logic validation module 15, referring to Figure 2, including

(i) extracting a first estimate of system state from the approved measurement passed from the fuzzy logic validation module 15;

(ii) extracting a second estimate of system state from the corrected measurement sent from the fuzzy logic validation module 15; and

(iii) predicting a third estimate of system state without measurement data when receiving the rejected measurement flag from the fuzzy logic validation module 15.

(e) output the obtained first, second and third estimates of system state by a state estimate output interface 90.

Referring to Figure 1, the fuzzy logic validation step (c) of the filtering process of the present invention provides a reference standard to examine the quality of the measurement. The kernel of the fuzzy logic validation is a fuzzy rule base, which is established from system dynamics characteristics and measurement relationships. The measurement data are of any nature, including but not limited to target position, velocity, and acceleration in the tracking applications, spectral intensity in different bands in the hyperspectral applications, and accelerometer and gyro measurements in inertial

navigation applications. Within the fuzzy logic validation, an expected measurement is computed and compared to the measurement input. When the discrepancy between the expected measurement and the measurement input lies in a prescribed acceptance range, the measurement input is considered to be useful and accepted. When the discrepancy between the expected measurement and the measurement input goes beyond a prescribed rejection range, the measurement input is considered to be useless and rejected. When the discrepancy between the expected measurement and the measurement input lies between the acceptance range and the rejection range, the measurement input is considered to be useful and corrected measurement data are generated.

The measurement data is provided by the measurement input interface 10 to the fuzzy logic validation module 15. Referring to Figure 3, the step (c) further comprises the following steps:

(c1) Receive the original measurement data from the measurement input interface 10 in a fuzzifier module 151. Perform a scale mapping on the original measurement data, which transfers the range of measurement into a corresponding universe of discourse. Perform fuzzification and convert the measurement data into suitable linguistic values which are labeled as fuzzy sets. Interpret the crisp measurement data as fuzzy sets with membership functions belonging to [0, 1]. Output these fuzzy sets to a fuzzy interface engine 152.

(c2) Receive the fuzzy sets from the fuzzifier module 151 in a fuzzy interface engine 152, wherein human decision making is simulated to infer fuzzy outputs, using fuzzy implication and the fuzzy logic inference rules, and the fuzzy logic inference rules are supported by a fuzzy rule base 153. Send the obtained fuzzy outputs to a defuzzifier module 154.

(c3) Provide the fuzzy logic inference rules for the fuzzy interface engine 152 in the fuzzy rule base 153 which characterizes goals and domain knowledge of experts by means of a set of linguistic rules, wherein the fuzzy rule base 153 comprises the knowledge of the application domain and the attendant goal. Primarily determine the performance of the fuzzy logic validation 15 by the fuzzy rule base 153.

(c4) Receive the fuzzy outputs from the fuzzy interface engine 152 in the defuzzifier module 154. Selectively, it approves the original measurement data (approved measurement) and passes it down without change to the state estimate module 20, generates a crisp corrected measurement data (corrected measurement) that best represents the possibility distribution of the inferred fuzzy outputs from the fuzzy interface engine 152 and outputs the corrected measurement data (corrected measurement) to the state estimate module 20, and rejects the measurement data and outputs the rejected-measurement flag to the state estimate module 20.

In the step (d), the output from the defuzzifier module 154 in the fuzzy logic validation module 15 is processed to produce the estimate of system state in the state estimate module 20. The state estimate module 20 of the present invention provides two options, forward filtering, referring to Figure 4, and backward smoothing, referring to Figure 5. Backward smoothing requires that forward filtering be executed first and forward filtering results are stored. Forward filtering is suitable for real-time applications, while backward smoothing is useful in non-real-time applications with a higher accuracy.

To accommodate randomly spaced measurement intervals, the measurement data is required to be clearly time-stamped, such that the interval span between two consecutive valid measurements is computed to monitor how long the state estimate propagates without a measurement update in a time update 202 in the state estimate module 20.

The first preferred processing of the step (d), forward filtering, as shown in Figure 4, further comprises the following steps.

(d1) Compute a model relevant information for the time update 202 and a measurement update 201 in a model selection 203. Specifically, the model selection 203 provides an initial condition of the system estimate for a system model computation 2021 in the time update 202, an initial condition of the covariance error matrix for a derivative system model computation 2022 in the time update 202, a system model for the system model computation 2021 in the time update 202, a derivative system model for the derivative system model computation 2022 in the time update 202, a measurement model for a measurement model computation 2011 in the measurement update 201, and a

derivative measurement model for a derivative measurement model computation 2012 in the measurement update 201.

(d2) Propagate the state estimate during the interval of the last two consecutive valid measurements in the time update 202. The time update is exclusively based upon the system model. Denote by $\hat{\mathbf{x}}(t_{k-1})$ and $\mathbf{P}(t_{k-1})$ the state estimate and its associated covariance error matrix at time t_{k-1}, respectively, just after the last measurement $\mathbf{z}(k-1)$ at t_{k-1} has been processed by the measurement update 201. The step (d2) also comprises the steps of:

(d2-1)

computing the interval span between the last two consecutive valid measurements $\mathbf{z}(k-1)$ and $\mathbf{z}(k)$. wherein this interval span, calculated by

$$t_k - t_{k-1}$$

determines how long the time update propagates without a measurement update;

(d2-2) receiving the system model from the model selection 203 and computing a time derivative of the system state at the latest estimate of the system state $\hat{\mathbf{x}}(t_{k-1})$ in the system model computation 2021,

$$\dot{\hat{\mathbf{x}}}(t_{k-1}) = \mathbf{f}(\hat{\mathbf{x}}(t_{k-1}))$$

(d2-3) receiving the derivative system model from the model selection 203 and computing a time derivative of a covariance error matrix for the system state at the latest estimate of the system state $\hat{\mathbf{x}}(t_{k-1})$ in the derivative system model computation 2022,

$$\dot{\mathbf{P}}(t_{k-1}) = \mathbf{F}(t_{k-1})\mathbf{P}(t_{k-1}) + \mathbf{P}(t_{k-1})\mathbf{F}^T(t_{k-1}) + \mathbf{Q}(t_{k-1})$$

where the Jacobian matrix $\mathbf{F}(t_{k-1})$ is calculated at $\hat{\mathbf{x}}(t_{k-1})$ by

$$F(t_{k-1}) = \frac{\partial f(x)}{\partial x}\Big|_{x=\hat{x}(t_{k-1})}$$

(d2-4) propagating the state estimate by utilizing the time derivative of the system state estimate $\hat{x}(t_{k-1})$ computed in the system model computation 2021 in a prediction update 2023, using a Runge-Kutta integration algorithm with adaptive stepsize control,

$$\hat{x}(t_{k-1}) \rightarrow \hat{x}(t_k)$$

(d2-5) propagating the covariance error matrix of the state estimate by utilizing the time derivative of the covariance error matrix $\dot{P}(t_{k-1})$ computed in the derivative system model computation 2022 in a prediction covariance update 2024, using a factorized implementation which is detailed later, to ensure the symmetry and positive definiteness of $P(t)$ during the propagation,

$$P(t_{k-1}) \rightarrow P(t_k)$$

(d3) Correct the state estimate by using the latest measurement data $z(k)$ at t_k in the measurement update 201. The measurement update is based upon the measurement model and the measurement data. In the case that a rejected-measurement flag is received corresponding to $z(k)$ from the fuzzy logic validation 15, the measurement update for $z(k)$ is skipped and the time update continues. When $z(k)$ is adopted, the results obtained in the time update are utilized as the initial conditions. Denote by $\hat{x}_-(k)$ and $P_-(k)$ the state estimate and its associated covariance error matrix at time t_k, respectively, obtained from the time update 202 just before the last measurement $z(k)$ at t_k is processed by the measurement update 201,

$$\hat{x}_-(k) = \hat{x}(t_k^-)$$
$$P_-(k) = P(t_k^-)$$

wherein the step (d3) further comprises the steps of:

(d3-1) receiving the measurement model from the model selection 203 and computing a predicted measurement at the latest estimate of the system state $\hat{\mathbf{x}}_-(k)$ in the measurement model computation 2011, as follows,

$$\hat{\mathbf{z}}(k) = \mathbf{h}(\hat{\mathbf{x}}_-(k))$$

(d3-2) receiving the derivative measurement model from the model selection 203 and computing a measurement Jacobian matrix at the latest estimate of the system state $\hat{\mathbf{x}}_-(k)$ in the derivative measurement model computation 2012,

$$\mathbf{H}(k) = \frac{\partial \mathbf{h}(\mathbf{x})}{\partial \mathbf{x}}\bigg|_{\mathbf{x}=\hat{\mathbf{x}}_-(k)}$$

(d3-3) updating the covariance error matrix using the measurement update equations in the estimate covariance update 2013, as follows,

$$\mathbf{P}_+(k) = [\mathbf{I} - \mathbf{K}(k)\mathbf{H}(k)]\mathbf{P}_-(k)$$
$$\mathbf{K}(k) = \mathbf{P}_-(k)\mathbf{H}'(k)\eta^{-1}(k)$$
$$\eta(k) = \mathbf{H}(k)\mathbf{P}_-(k)\mathbf{H}'(k) + \mathbf{R}(k)$$

wherein a factorized implementation is detailed later, to ensure the symmetry and positive definiteness of $\mathbf{P}_+(k)$.

(d3-4) updating the estimate of the system state using the measurement update equations in the estimate update 2014,

$$\hat{\mathbf{x}}_+(k) = \hat{\mathbf{x}}_-(k) + \mathbf{K}(k)[\mathbf{z}(k) - \hat{\mathbf{z}}(k)]$$

The steps (d2) and (d3) constitute a complete forward filtering process for the measurement data $\mathbf{z}(k)$. When a new valid measurement data $\mathbf{z}(k+1)$ becomes available, a new time update is initiated, based on the initial conditions,

$$\hat{\mathbf{x}}(t_k) = \hat{\mathbf{x}}_+(k)$$
$$\mathbf{P}(t_k) = \mathbf{P}_+(k)$$

It should be noted that the universal robust filter is applicable to practically any applications, because the user is allowed to change the system model and measurement model to fit his/her own applications via the model selection 203. The model selection is an integral part of the universal robust filter. The system model is described in nonlinear continuous-time differential equations. The measurable model is formulated in nonlinear discrete-time equations.

In some applications where a real time requirement is not stringent and higher accuracy is desired, backward smoothing, which exploits future measurements to improve the current state estimates. is useful. Backward smoothing is not started until the predetermined range of the measurement data has been received. Smoothing is performed backwards in time. The backward filter operates recursively on the measurement data, beginning at the terminal time and proceeding toward the desired smoothing point.

Referring to Figure 5, the universal robust filter 21 for backward smoothing includes a model selection 213, a forward measurement update 211, a forward time update 212, a backward measurement update 214, and a backward time update 215. The forward measurement update 211 and the forward time update 212 comprise the forward filtering portion. The forward measurement update 211, the forward time update 212, as well as their contained subblocks, a measurement model computation 2111, a derivative measurement model computation 2112, an estimate covariance update 2113, an estimate update 2114, a system model computation 2121, a derivative system model computation 2122, a prediction update 2123, a prediction covariance update 2124, are exactly the same as their corresponding blocks in Figure 4. The backward measurement update 214 and the backward time update 215 include the backward filtering portion. Forward filtering results and backward filtering results are combined in a smoothed estimate covariance update 216 and a smoothed estimate update 217 to provide smoothed results.

Referring to Figure 5, the second preferred processing of the step (d), backward smoothing, further comprises the following additional steps:

(d4) Calculate the interval from which a backward smoothed estimate is extracted. By defining $\tau = T - t$ and $\tau_k = T - t_{N-k}$ with T the terminal time, the system dynamic equation and the measurement equation are reformulated as

$$\frac{\mathrm{d}}{\mathrm{d}\tau}\mathbf{x}(T-\tau) = -\mathbf{f}(\mathbf{x}(T-\tau)) + \mathbf{w}(T-\tau)$$
$$\mathbf{z}(N-k) = \mathbf{h}(\mathbf{x}(N-k)) + \mathbf{v}(N-k)$$

(d5) Perform the first preferred processing steps D2 (D2-1 ~ D2-5) and D3 (D3-1 ~ D3-4) to compute the forward state estimate $\hat{\mathbf{x}}(t)$ and its covariance error matrix $\mathbf{P}(t)$ in the forward measurement update 211 and the forward time update 212.

(d6) Propagate the backward estimate during the interval of the last two consecutive reversed measurements in the backward time update 215. The backward time update is exclusively based upon the backward system model. Define $\hat{\mathbf{x}}_b(\tau_{k-1})$ and $\mathbf{P}_b(\tau_{k-1})$ the backward state estimate and its associated covariance error matrix for the backward system model at time τ_{k-1}, respectively, just after the last reversed measurement $\mathbf{z}(N - k + 1)$ has been processed by the backward measurement update 214. The initial condition, $\hat{\mathbf{x}}_b(0)$, is chosen as $\hat{\mathbf{x}}(T)$, and the initial condition, $\mathbf{P}_b(0)$, is set to be a diagonal matrix with large diagonal elements, wherein the step (d6) further comprise the steps of:

(d6-1) computing the interval span between the last two consecutive reserved valid measurements $\mathbf{z}(N - k + 1)$ and $\mathbf{z}(N - k)$. This interval span, $\tau_k - \tau_{k-1} = t_{N-k+1} - t_{N-k}$, determines how long the backward time update propagates without a measurement update;

(d6-2) receiving the system model and the derivative system model from the model selection 213, computing a system function and a Jacobian matrix at the forward state estimate $\hat{\mathbf{x}}(T-\tau_{k-1})$ obtained in forward filtering, and calculating a time derivative of the backward system state in the system model computation 2151,

$$\dot{\hat{\mathbf{x}}}_b(\tau_{k-1}) = -\mathbf{f}(\hat{\mathbf{x}}(T-\tau_{k-1})) - \mathbf{F}(T-\tau_{k-1})\left[\hat{\mathbf{x}}_b(\tau_{k-1}) - \hat{\mathbf{x}}(T-\tau_{k-1})\right]$$

where the Jacobian matrix $\mathbf{F}(T-\tau_{k-1})$ is calculated at $\hat{\mathbf{x}}(T-\tau_{k-1})$ by

$$\mathbf{F}(T-\tau_{k-1}) = \frac{\partial \mathbf{f}(\mathbf{x})}{\partial \mathbf{x}}\Big|_{\mathbf{x}=\hat{\mathbf{x}}(T-\tau_{k-1})}$$

(d6-3) receiving the derivative system model from the model selection 213 and computing a time derivative of the covariance error matrix for the backward system state at the forward state estimate $\hat{\mathbf{x}}(T-\tau_{k-1})$ in the derivative system model computation 2152,

$$\dot{\mathbf{P}}_b(\tau_{k-1}) = -\mathbf{F}(T-\tau_{k-1})\mathbf{P}_b(\tau_{k-1}) - \mathbf{P}_b(\tau_{k-1})\mathbf{F}'(T-\tau_{k-1}) + \mathbf{Q}(T-\tau_{k-1})$$

(d6-4) propagating the backward state estimate by utilizing the time derivative of the backward system state $\dot{\hat{\mathbf{x}}}_b(\tau_{k-1})$ computed in the system model computation 2151 in a backward prediction update 2154, using a Runge-Kutta integration algorithm with adaptive stepsize control,

$$\hat{\mathbf{x}}_b(\tau_{k-1}) \rightarrow \hat{\mathbf{x}}_b(\tau_k)$$

(d6-5) propagating the covariance error matrix of the backward state estimate by utilizing the time derivative of the covariance error matrix $\dot{\mathbf{P}}_b(\tau_{k-1})$ computed in the derivative system model computation 2152 in a backward prediction covariance update 2153, using a factorized implementation which is detailed later, to ensure the symmetry and positive definiteness of $\mathbf{P}_b(\tau)$ during the propagation,

$$\mathbf{P}_b(\tau_{k-1}) \rightarrow \mathbf{P}_b(\tau_k)$$

(d7) Correct the backward state estimate by using the reversed measurement data $\mathbf{z}(N-k)$ at time τ_k in the backward measurement update 214. The measurement update is based upon the measurement model and the measurement data. The results obtained in the backward time update are utilized as the initial conditions. Denote by $\hat{\mathbf{x}}_{b-}(k)$ and $\mathbf{P}_{b-}(k)$ the backward state estimate and its associated covariance error matrix at time τ_k, respectively, obtained from the backward time update 215 just before the new

reversed measurement $\mathbf{z}(N-k)$ at time τ_k is processed by the backward measurement update 214.

$$\hat{\mathbf{x}}_{b-}(k) = \hat{\mathbf{x}}_b(\tau_k^-)$$
$$\mathbf{P}_{b-}(k) = \mathbf{P}_b(\tau_k^-)$$

wherein the step (d7) further comprises the steps of:

(d7-1) receiving the measurement model from the model selection 213 and computing a predicted measurement at the forward state estimate $\hat{\mathbf{x}}(N-k)$ in the measurement model computation 2141,

$$\hat{\mathbf{z}}_b(k) = \mathbf{h}(\hat{\mathbf{x}}(N-k))$$

(d7-2) receiving the derivative measurement model from the model selection 213 and computing a measurement Jacobian matrix at the forward state estimate $\hat{\mathbf{x}}(N-k)$ in the derivative measurement model computation 2142,

$$\mathbf{H}(N-k) = \frac{\partial \mathbf{h}(\mathbf{x})}{\partial \mathbf{x}}\Big|_{\mathbf{x}=\hat{\mathbf{x}}(N-k)}$$

(d7-3) updating the covariance error matrix of the backward system estimate using the backward measurement update equations in the backward estimate covariance update 2143,

$$\mathbf{P}_{b+}(k) = \left[\mathbf{I} - \mathbf{K}_b(k)\mathbf{H}(N-k)\right]\mathbf{P}_{b-}(k)$$
$$\mathbf{K}_b(k) = \mathbf{P}_{b-}(k)\mathbf{H}'(N-k)\eta_b^{-1}(k)$$
$$\eta_b(k) = \mathbf{H}(N-k)\mathbf{P}_{b-}(k)\mathbf{H}'(N-k) + \mathbf{R}(N-k)$$

wherein a factorized implementation is detailed later, to ensure the symmetry and positive definiteness of $\mathbf{P}_{b+}(k)$,

(d7-4) updating the backward state estimate using the backward measurement update equations in the backward estimate update 2144,

$$\hat{\mathbf{x}}_{b+}(k) = \hat{\mathbf{x}}_{b-}(k) + \mathbf{K}_b(k)\left[\mathbf{z}(N-k) - \hat{\mathbf{z}}_b(k) - \mathbf{H}(N-k)\left(\hat{\mathbf{x}}_{b-}(k) - \hat{\mathbf{x}}(N-k)\right)\right]$$

The steps (d6) and (d7) constitute a complete backward filtering process for the reversed measurement data $\mathbf{z}(N-k)$. For the next reversed measurement data $\mathbf{z}(N-k-1)$, a new backward time update is started, based on the initial conditions,

$$\hat{\mathbf{x}}_b(\tau_k) = \hat{\mathbf{x}}_{b+}(k)$$
$$\mathbf{P}_b(\tau_k) = \mathbf{P}_{b+}(k)$$

(d8) Compute a covariance error matrix for a smoothed state estimate using the covariance error matrix of the forward system estimate and the covariance error matrix of the backward system estimate in a smoothed estimate covariance update 216,

$$\mathbf{P}(t|T) = \left[\mathbf{P}^{-1}(t) + \mathbf{P}_b^{-1}(t)\right]^{-1}$$

(d9) Compute the smoothed state estimate using the forward system estimate and the backward system estimate in a smoothed estimate update 217,

$$\hat{\mathbf{x}}(t|T) = \mathbf{P}(t|T)\left[\mathbf{P}^{-1}(t)\hat{\mathbf{x}}(t) + \mathbf{P}_b^{-1}(t)\hat{\mathbf{x}}_b(t)\right]$$

To assure filtering/smoothing accuracy and numerical stability, the propagation of the covariance error matrix is accomplished using a factorized implementation. Instead of computing $\mathbf{P}(t)$, the factorized implementation propagates $\mathbf{P}^{1/2}(t)$ at each iteration, where $\mathbf{P}(t) = \mathbf{P}^{1/2}(t)\ \mathbf{P}^{T/2}(t)$, $\mathbf{P}^{1/2}(t)$ is a lower triangular matrix, and $\mathbf{P}^{T/2}(t)$ is the upper triangular transpose of $\mathbf{P}^{1/2}(t)$.

In the step (d2-5), updating $\mathbf{P}^{T/2}(t_{k-1})$ from time t_{k-1} to $t_{k-1}+\Delta t$ is accomplished using the numerically stable QR decomposition,

$$\mathbf{P}^{T/2}(t_{k-1}) + \left[\mathbf{P}^{T/2}(t_{k-1})\mathbf{F}^{T}(t_{k-1}) + \tfrac{1}{2}\mathbf{P}^{-1/2}(t_{k-1})\mathbf{Q}(t_{k-1})\right]\Delta t = \Gamma_1\ \ \mathbf{P}^{T/2}(t_{k-1} + \Delta t)$$

The above QR decomposition is completed in two steps. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_1 an orthogonal matrix which satisfies $\Gamma_1^T \Gamma_1 = \mathbf{I}$. In this process, the orthogonal matrix Γ_1 is not required to be saved. Only the upper triangular matrix $\mathbf{P}^{T/2}(t_{k-1}+\Delta t)$, which is the updated covariance error matrix, is needed to be kept.

Referring to Figure 6, the time step used in updating $\mathbf{P}^{T/2}(t_{k-1})$ from time t_{k-1}, Δt, is inherited from step D2-4, in which a Runge-Kutta integration algorithm with adaptive stepsize control is used. Based on the current state estimate, $\hat{\mathbf{x}}(t_{k-1})$, and the time derivative of the system state, $\dot{\hat{\mathbf{x}}}(t_{k-1})$, the Runge-Kutta adaptive stepsize control integration algorithm produces the stepsize to propagate the state estimate, Δt, and the updated state estimate, $\hat{\mathbf{x}}(t_{k-1}+\Delta t)$. It is thus possible that multiple steps are taken for updating $\hat{\mathbf{x}}(t_{k-1})$ from time t_{k-1} to t_k. Updating of $\mathbf{P}^{T/2}(t_{k-1})$ from time t_{k-1} to t_k follows the exactly same time steps as those used in updating $\hat{\mathbf{x}}(t_{k-1})$ from time t_{k-1} to t_k.

In the step (d3-3), updating the covariance error matrix in the measurement update is accomplished using QR decomposition,

$$\begin{pmatrix} \mathbf{R}^{T/2}(k) & 0 \\ \mathbf{P}_-^{T/2}(k)\mathbf{H}^T(k) & \mathbf{P}_-^{T/2}(k) \end{pmatrix} = \Gamma_2 \begin{pmatrix} \eta^{T/2}(k) & \eta^{-1/2}(k)\mathbf{H}(k)\mathbf{P}_-(k) \\ 0 & \mathbf{P}_+^{T/2}(k) \end{pmatrix}$$

The QR decomposition is completed similarly. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_2 an orthogonal matrix which satisfies $\Gamma_2^T \Gamma_2 = \mathbf{I}$. The orthogonal matrix Γ_2 is not required to be saved either.

In the step (d3-4), updating the state estimate in the measurement update is accomplished by utilizing the results obtained in the QR decomposition, as follows,

$$\hat{\mathbf{x}}_+(k) = \hat{\mathbf{x}}_-(k) + \underbrace{\mathbf{P}_-(k)\mathbf{H}^T(k)\eta^{-T/2}(k)}_{\text{available in (1,2)-block}}\,\eta^{-1/2}(k)\left[\mathbf{z}(k) - \hat{\mathbf{z}}(k)\right]$$

The gain above is composed of two terms available from the QR decomposition. The first term, $\mathbf{P}_{-}(k)\mathbf{H}^T(k)\eta^{-T/2}(k)$, is directly derived from the transpose of the (1, 2)-block of the right-hand side upper triangular matrix. The second term, $\eta^{-1/2}(k)$, is calculated from the inversion of the (1, 1)-block of the right-hand side upper triangular matrix.

In the step (d6-5), updating $\mathbf{P}_b^{T/2}(\tau_{k-1})$ from time τ_{k-1} to $\tau_{k-1}+\Delta\tau$ is accomplished using QR decomposition,

$$\mathbf{P}_b^{T/2}(\tau_{k-1}) + \left[-\mathbf{P}_b^{T/2}(\tau_{k-1})\mathbf{F}^T(T-\tau_{k-1}) + \tfrac{1}{2}\mathbf{P}_b^{-1/2}(\tau_{k-1})\mathbf{Q}(T-\tau_{k-1})\right]\Delta\tau = \Gamma_3 \; \mathbf{P}_b^{T/2}(\tau_{k-1}+\Delta\tau)$$

The QR decomposition is completed in a similar way. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_3 an orthogonal matrix which satisfies $\Gamma_3^T\Gamma_3 = \mathbf{I}$. The orthogonal matrix Γ_3 does not have to be saved.

The time step used in updating $\mathbf{P}_b^{T/2}(\tau_{k-1})$ from time τ_{k-1}, $\Delta\tau$, is obtained in a similar way to that in forward filtering. In the step (d6-4), based on the current backward state estimate, $\hat{\mathbf{x}}_b(\tau_{k-1})$, and the time derivative of the system state, $\dot{\hat{\mathbf{x}}}_b(\tau_{k-1})$, a Runge-Kutta integration algorithm with adaptive stepsize control produces the stepsize to propagate the backward state estimate, $\Delta\tau$, and the updated state estimate, $\hat{\mathbf{x}}_b(\tau_{k-1}+\Delta\tau)$. It is possible that multiple steps are taken for updating $\hat{\mathbf{x}}_b(\tau_{k-1})$ from time τ_{k-1} to τ_k. Updating of $\mathbf{P}_b^{T/2}(\tau_{k-1})$ from time τ_{k-1} to τ_k follows the exactly same time steps as those used in updating $\hat{\mathbf{x}}_b(\tau_{k-1})$ from time τ_{k-1} to τ_k.

In the step (d7-3), updating the backward covariance error matrix in the backward measurement update is accomplished using QR decomposition,

$$\begin{pmatrix} \mathbf{R}^{T/2}(N-k) & 0 \\ \mathbf{P}_{b-}^{T/2}(k)\mathbf{H}^T(N-k) & \mathbf{P}_{b-}^{T/2}(k) \end{pmatrix} = \Gamma_4 \begin{pmatrix} \eta_b^{T/2}(k) & \eta_b^{-1/2}(k)\mathbf{H}(N-k)\mathbf{P}_{b-}(k) \\ 0 & \mathbf{P}_{b+}^{T/2}(k) \end{pmatrix}$$

The QR decomposition is completed similarly. First, the matrix on the left-hand side is constructed. Then, QR decomposition is performed on the constructed matrix, and the right-hand side matrices are obtained, with Γ_4 an orthogonal matrix which satisfies $\Gamma_4^T\Gamma_4 = \mathbf{I}$. The orthogonal matrix Γ_4 is not required to be saved either.

In the step (d7-4), updating the backward state estimate in the backward measurement update is accomplished by utilizing the results obtained in the QR decomposition,

$$\hat{\mathbf{x}}_{b+}(k) = \hat{\mathbf{x}}_{b-}(k) + \mathbf{K}_b(k)\left[\mathbf{z}(N-k) - \hat{\mathbf{z}}_b(k) - \mathbf{H}(N-k)\left(\hat{\mathbf{x}}_{b-}(k) - \hat{\mathbf{x}}(N-k)\right)\right]$$
$$\mathbf{K}_b(k) = [1,2]^T \; [1,1]^{-T}$$

where the gain matrix, $\mathbf{K}_b(k)$, is composed of two terms available from the QR decomposition. The first term, $\mathbf{P}_{b-}(k)\ \mathbf{H}^T(N-k)\ \eta_b^{-T/2}(k)$, is directly derived from the transpose of the (1, 2)-block of the right-hand side upper triangular matrix. The second term, $\eta_b^{-1/2}(k)$, is calculated from the inversion of the (1, 1)-block of the right-hand side upper triangular matrix.

The present invention is highly applicable to hyperspectral image processing to detect the presence of a particular material and classify the comprising materials. Hyperspectral image sets contain large amounts of data that are difficult to exploit. Most materials have unique spectral signatures and if that signature can be observed or detected, then these materials can be identified with certainty. Prior techniques for hyperspectral imagery exploitation use classical pattern recognition methods. These methods include model based or least squares approaches to detect and classify materials present in the data. The present invention can be applied to hyperspectral image processing and pixel unmixing.

The application of the present invention to hyperspectral image processing comprises the following steps.

Select the system state elements to be the square root of abundance of the candidate materials, which guarantees the nonnegativeness of the abundance.

Establish a dynamical system model, by converting a two-dimensional spatial index (x, y) into a one-dimensional index k, and assume that the relationship of the square root of the abundance between two adjacent pixels is modeled as a Gauss-Markov

process. The rule to the index conversion is that two consecutive pixel in one-dimension indexing must be physically adjacent.

Establish a measurement model, by assuming that the spectrum of a pixel is modeled as a linear mixture of spectral signatures of materials within the pixel. The constraint that the sum of abundance of all materials within a pixel equals to 1.0 is translated into an extra measurement equation.

Apply the universal robust filtering process in the present invention to estimate the abundance of the comprising materials for each pixel.

It should be noted that the system model established in the above steps is a discrete-time difference model, which is determined by the inherent discrete nature of the hyperspectral problem. The adaptive stepsize control of the present invention is thus unnecessary for the hyperspectral applications. Also, the system model is linear, based upon the Gauss-Markov process assumption for the relationship of the square root of the abundance between two adjacent pixels. Therefore, the hyperspectral image processing is nicely embodied into the application domain of the present invention as a special case.

What is Claimed is:

1. A filtering process, comprising the steps of:

(a) computing a model relevant information for a time update and a measurement update in a model selection; and

(b) providing, from said model selection, an initial condition of a system estimate for a system model computation in said time update, an initial condition of a covariance error matrix for a derivative system model computation in said time update, a system model for said system model computation in said time update, a derivative system model for said derivative system model computation in said time update, a measurement model for a measurement model computation in said measurement update, and a derivative measurement model for a derivative measurement model computation in said measurement update.

2. The filtering process, further comprising the steps of:

(c) propagating said state estimate during an interval of last two consecutive valid measurements in said time update which is based upon a system model; and

(d) correcting said state estimate by using a latest measurement data in said measurement update, said measurement update being based upon said measurement model and said measurement data;

3. The filtering process, as recited in claim 2, wherein said step (c) further comprises the steps of:

(c-1) computing an interval span between said last two consecutive valid measurements in order to determine how long said time update propagates without said measurement update;

(c-2) receiving said system model from a model selection and computing a time derivative of said system state at a latest estimate of said system state in said system model computation;

(c-3) receiving said derivative system model from said model selection and computing a time derivative of a covariance error matrix for said system state at said latest estimate of said system state in said derivative system model computation;

(c-4) propagating said state estimate by utilizing said time derivative of said system state computed in said system model computation in a prediction update, using a Runge-Kutta integration algorithm with adaptive stepsize control; and

(c-5) propagating said covariance error matrix of said state estimate by utilizing said time derivative of said covariance error matrix computed in said derivative system model computation in a prediction covariance update, using a factorized implementation.

4. The filtering process, as recited in claim 2, wherein said step (d) further comprises the steps of:

(d-1) receiving said measurement model from said model selection and computing a predicted measurement at a latest estimate of system state in said measurement model computation,

(d-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said latest estimate of system state in said derivative measurement model computation,

(d-3) updating said covariance error matrix by using measurement update equations in said estimate covariance update, and

(d-4) updating an optimal estimate of system state by using said measurement update equations in said estimate update.

5. The filtering process, as recited in claim 3, wherein said step (d) further comprises the step of:

(d-1) receiving said measurement model from said model selection and computing a predicted measurement at a latest estimate of system state in said measurement model computation,

(d-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said latest estimate of system state in said derivative measurement model computation,

(d-3) updating said covariance error matrix by using measurement update equations in said estimate covariance update, and

(d-4) updating an optimal estimate of system state by using said measurement update equations in said estimate update.

6. The filtering process, as recited in claim 4, after the step (d), further comprising the steps of:

(e) calculating an interval from which a backward smoothed estimate is extracted;

(f) obtaining said forward state estimate and a covariance error matrix thereof in a forward measurement update and a forward time update by performing the step (c) and the step (d);

(g) propagating a backward estimate during said interval of said last two consecutive reversed measurements in a backward time update based upon said backward system model so as to define said backward state estimate and said associated covariance error matrix thereof for said backward system model respectively, just after said last reversed measurement being processed by said backward measurement update;

(h) correcting said backward state estimate by using said reversed measurement data in a backward measurement update based upon said measurement model and said measurement data, wherein results obtained in said backward time update are utilized as initial conditions, wherein a state estimate and an associated covariance error matrix thereof obtained from said backward time update just before a new measurement is processed by said backward measurement update;

(i) computing a covariance error matrix for a smoothed state estimate using said covariance error matrix of said forward system estimate and said covariance error matrix of said backward system estimate in a smoothed estimate covariance update; and

(j) computing said smoothed state estimate using said forward system estimate and said backward system estimate in a smoothed estimate update.

7. The filtering process, as recited in claim 5, after the step (d), further comprising the steps of:

(e) calculating an interval from which a backward smoothed estimate is extracted;

(f) obtaining said forward state estimate and a covariance error matrix thereof in a forward measurement update and a forward time update by performing the step (c) and the step (d);

(g) propagating a backward estimate during said interval of said last two consecutive reversed measurements in a backward time update based upon said backward system model so as to define said backward state estimate and said associated covariance error matrix thereof for said backward system model respectively, just after said last reversed measurement being processed by said backward measurement update;

(h) correcting said backward state estimate by using said reversed measurement data in a backward measurement update based upon said measurement model and said measurement data, wherein results obtained in said backward time update are utilized as initial conditions, wherein a state estimate and an associated covariance

error matrix thereof obtained from said backward time update just before a new measurement is processed by said backward measurement update;

(i) computing a covariance error matrix for a smoothed state estimate using said covariance error matrix of said forward system estimate and said covariance error matrix of said backward system estimate in a smoothed estimate covariance update; and

(j) computing said smoothed state estimate using said forward system estimate and said backward system estimate in a smoothed estimate update.

8. The filtering process, as recited in claim 6, wherein said step (g) further comprise said steps of:

(g-1) computing said interval span between said last two consecutive reserved valid measurements so as to determine how long said backward time update propagates without a measurement update;

(g-2) receiving said system model and said derivative system model from a model selection, computing a system function and a Jacobian matrix at said forward state estimate obtained in forward filtering, and calculating a time derivative of said backward system state in a system model computation;

(g-3) receiving said derivative system model from said model selection and computing a time derivative of said covariance error matrix for said backward system state at said forward state estimate in a derivative system model computation;

(g-4) propagating said backward state estimate by utilizing said time derivative of said backward system state computed in said system model computation in a backward prediction update, using a Runge-Kutta integration algorithm with adaptive stepsize control; and

(g-5) propagating said covariance error matrix of said backward state estimate by utilizing said time derivative of said covariance error matrix computed in said

derivative system model computation in a backward prediction covariance update, using a factorized implementation.

9. A universal robust filtering process, as recited in claim 7, wherein said step (g) further comprise said steps of:

(g-1) computing said interval span between said last two consecutive reserved valid measurements so as to determine how long said backward time update propagates without a measurement update;

(g-2) receiving said system model and said derivative system model from a model selection, computing a system function and a Jacobian matrix at said forward state estimate obtained in forward filtering, and calculating a time derivative of said backward system state in a system model computation;

(g-3) receiving said derivative system model from said model selection and computing a time derivative of said covariance error matrix for said backward system state at said forward state estimate in a derivative system model computation;

(g-4) propagating said backward state estimate by utilizing said time derivative of said backward system state computed in said system model computation in a backward prediction update, using a Runge-Kutta integration algorithm with adaptive stepsize control; and

(g-5) propagating said covariance error matrix of said backward state estimate by utilizing said time derivative of said covariance error matrix computed in said derivative system model computation in a backward prediction covariance update, using a factorized implementation.

10. The filtering process, as recited in claim 6, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

11. The filtering process, as recited in claim 7, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

12. The filtering process, as recited in claim 8, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

13. The filtering process, as recited in claim 9, wherein said step (h) further comprise said steps of:

(h-1) receiving said measurement model from said model selection and computing a predicted measurement at said forward state estimate in a measurement model computation;

(h-2) receiving said derivative measurement model from said model selection and computing a measurement Jacobian matrix at said forward state estimate in a derivative measurement model computation;

(h-3) updating said covariance error matrix of said backward system estimate using said backward measurement update equations in a backward estimate covariance update; and

(h-4) updating said backward state estimate by using said backward measurement update equations in a backward estimate update.

Filtering Process for Stable and Accurate Estimation

Abstract of the Disclosure

A filtering process is adapted for eliminating the need of prediscretizing a continuous-time differential model into a discrete-time difference model. It provides a universal robust solution to the most general formulation, in the sense that the system dynamics are described by nonlinear continuous-time differential equations, and the nonlinear measurements are taken at intermittent discrete times randomly spaced. The filtering process includes the procedures of validating the measurement using fuzzy logic, and incorporating factorized forward filtering and backward smoothing to guarantee numerical stability. It provides users a reliable and convenient solution to extracting internal dynamic system state estimates from noisy measurements, with wider applications, better accuracy, better stability, easier design, and easier implementation.

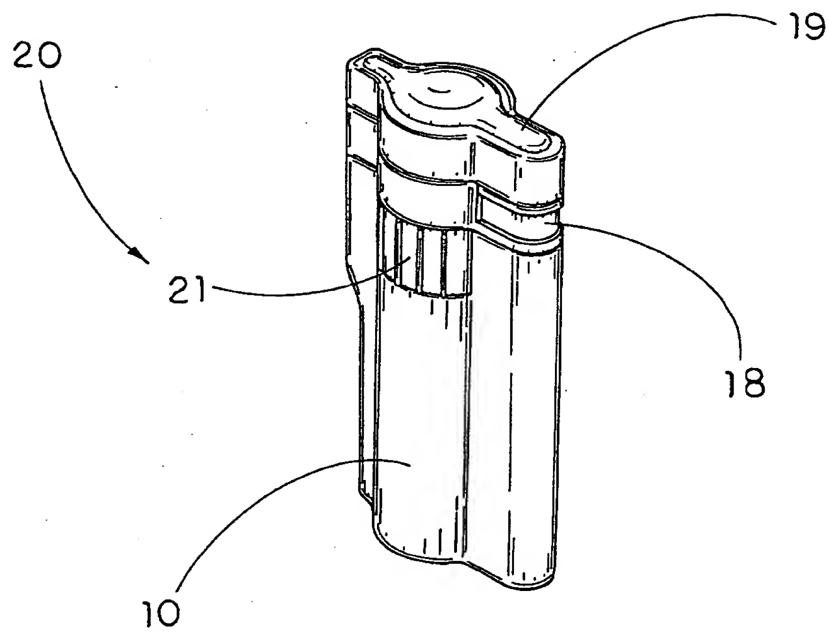

FIG.1

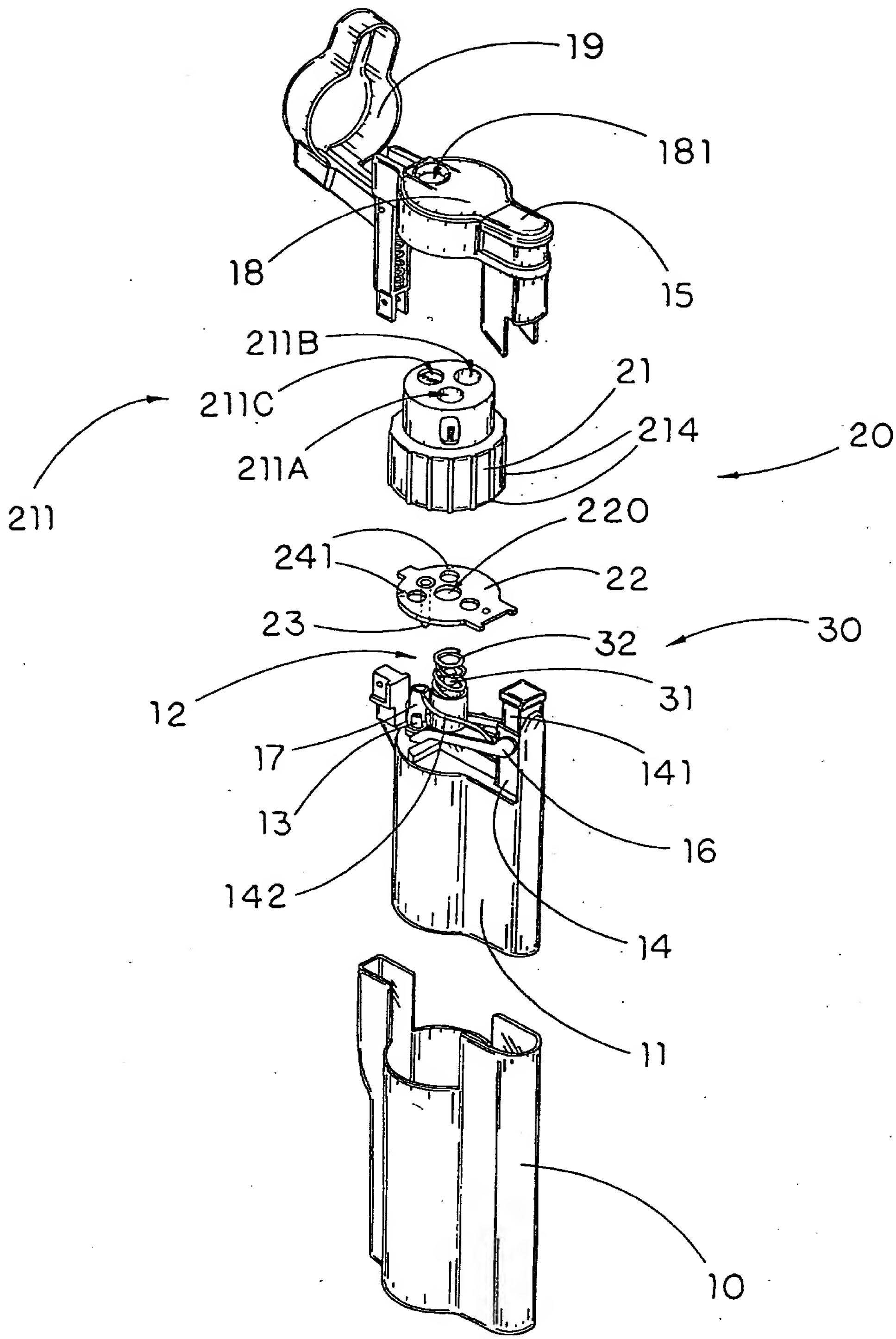
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FIG.2

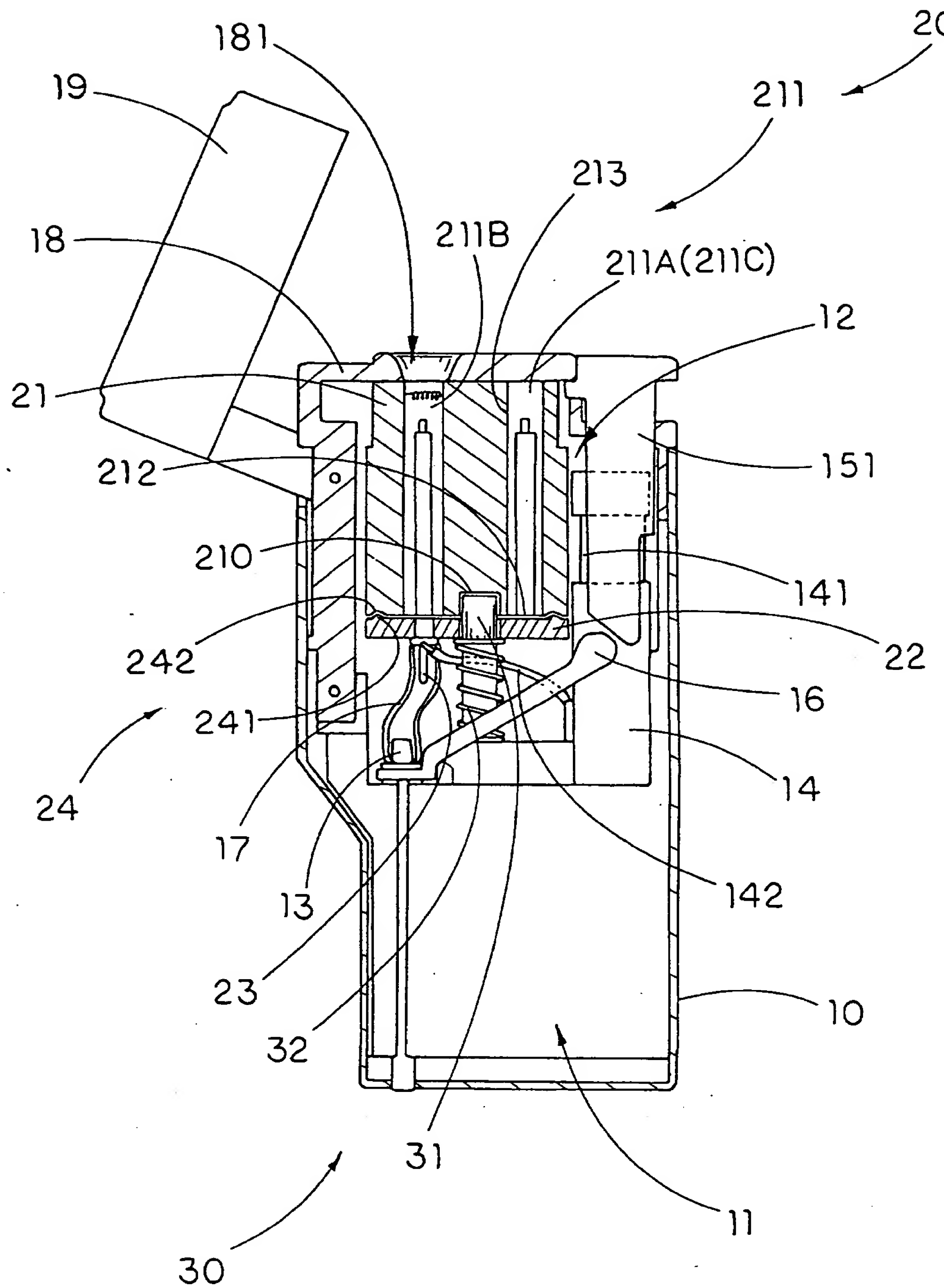
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FIG.3

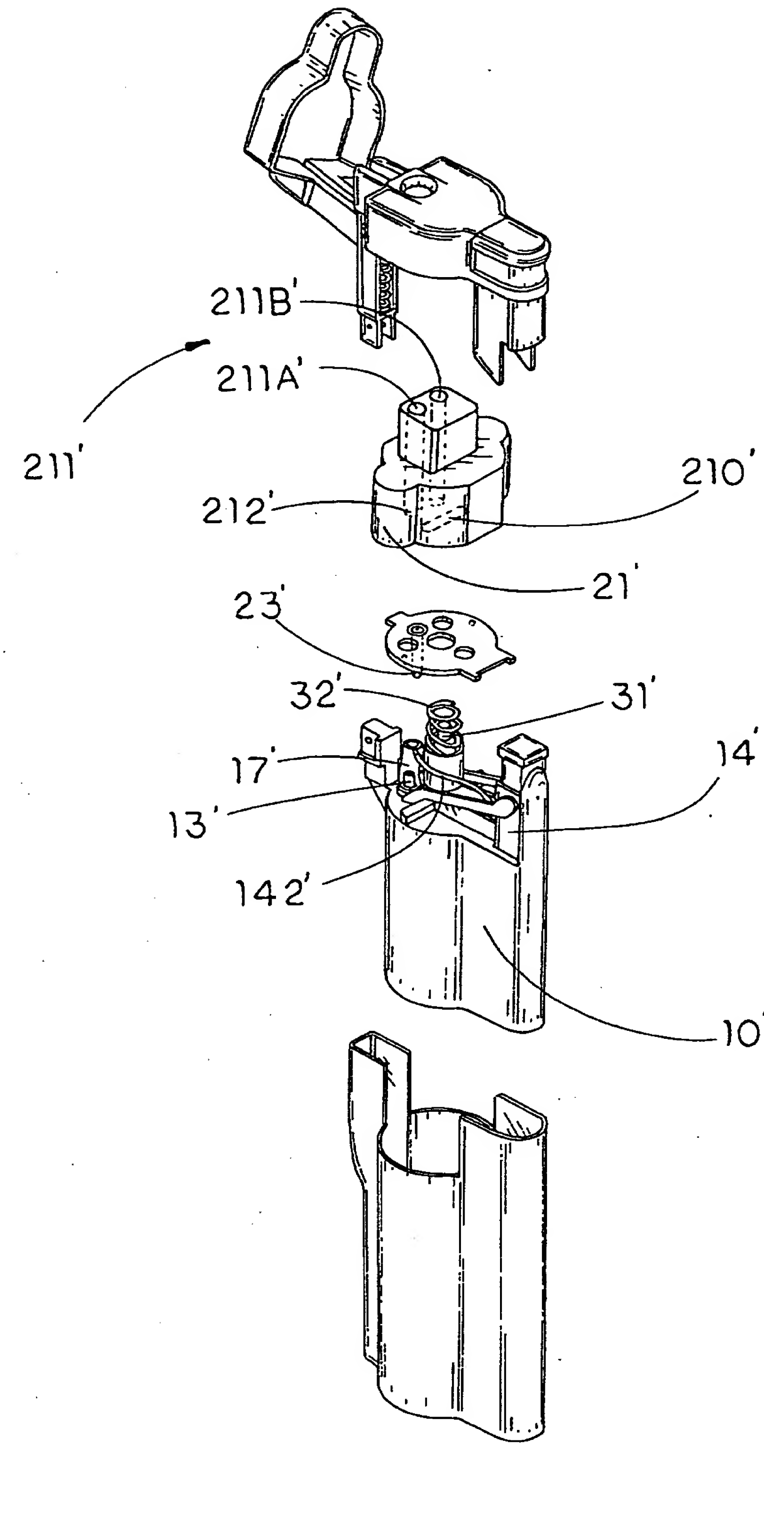

FIG.4

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Application deficiencies found during scanning:

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OFFICE OF PETITIONS

In re Application of
CHING-FANG LIN
Application No. 09/840,511
Filed: April 20, 2001
Attorney Docket No. USP1503A-GNC

: DECISION GRANTING PETITION

This is a decision on the communication filed May 22, 2003, which is being treated as a petition under 37 CFR 1.53(e) to request that the above-identified application be accorded a filing date of April 20, 2001, with Figures 1-6 as part of the original disclosure.

On April 20, 2001, applicant filed the above-identified application. On June 14, 2001, the Office of Initial Patent Examination mailed a "Notice to File Missing Parts of a Nonprovisional Application" (Notice), requiring the submission of an executed oath or declaration and a surcharge for its late filing. Additionally, the Notice stated that the application had been accorded a filing date of April 20, 2001, and advised applicant that Figures 5 and 6 appeared to have been omitted.

In response, on May 9, 2003, applicant filed a request for a corrected filing receipt and a copy of Figures 1-6. On May 22, 2003, applicant submitted the present petition and a copy of applicant's postcard receipt acknowledging receipt of 6 sheets of drawings (Figures 1-6) on April 20, 2001. Additionally, applicant submitted a copy of the 6 sheets of drawings.

Upon review of the record, it appears that the 4 drawing sheets in the application file on April 20, 2001, were <u>not</u> intended for the present application. However, the evidence is convincing that the application papers deposited on April 20, 2001, included 6 drawing sheets (Figures 1-6), which were subsequently misplaced in the United States Patent and Trademark Office. Therefore, the application, including 6 drawing sheets, was complete on filing and will be granted a filing date of April 20, 2001.

The present application will be <u>reprocessed</u> with the 6 sheets of drawings submitted on May 9, 2003.

Accordingly, the petition is granted.

The requirement for omitted Figures 5 and 6 set for in the Notice of June 14, 2001, was sent in error and is hereby vacated. Therefore, the $130.00 petition fee will be credited to Deposit Account No. 50-2111.

The application file is being forwarded to the Office of Initial Patent Examination for reprocessing and according the filing date of April 20, 2001, using Figures 1-6 submitted on petition. The Office records should indicate that 6 sheets of drawings were submitted on filing.

Any inquiries related to this decision should be directed to the undersigned at (703) 306-5589.

Christina T. Donnell

Christina Tartera Donnell
Senior Petitions Attorney
Office of Petitions

#10
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5/22/03
CTD of OP

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Fax Cover Sheet

DATE:	MAY 22, 2003	TIME:	2:25:50 PM
TO:	MR. MARK POLUTTA USPTO	OUR REF.:	USP1503A-GNC
PHONE:	703-308-8122	FAX:	703-746-3465
FROM:	David & Raymond	PHONE: FAX:	(626) 571-9812 (626) 571-9813
RE:	09/840,511 (Filtering Process for Stable and Accurate Estimation)		

Number of pages including cover sheet: 2

Dear Mr. Polutta,

With reference to our previous telephone conversation earlier on today, I have enclosed herewith a copy of the returned postcard of the case in concern (application serial number 09/840,511, filing date 04/20/2001, title "Filtering Process for Stable and Accurate Estimation").

Thank you for your attention and please do not hesitate to contact our firm should you have any queries concerning the above.

Sincerely,

Raymond Y. Chan

David & Raymond

~~Adjustment date: 07/16/2003 AKELLEY~~
~~05/14/2003 EFLORES 00000155 09840511~~
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Repln. Ref: 07/16/2003 AKELLEY 00103770200
DAM:502111 Name/Number:09840511
FC: 9204 $130.00 CR